State of California

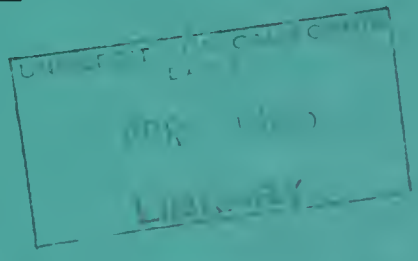
THE RESOURCES AGENCY

Department of Water Resources

BULLETIN No. 96

SOUTHERN TUOLUMNE COUNTY INVESTIGATION

Preliminary Edition



MARCH 1965

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Director
Department of Water Resources

ERRATA SHEET

On page 52, line 12, "transportation" should read "transpiration"; on page 80, line 17, "protect" should read "protest".

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ATE OF CALIFORNIA—RESOURCES AGENCY
EPARTMENT OF WATER RESOURCES
O. BOX 388
CRAMENTO

WILLIAM E. WARNE, *Director*

November 27, 1964

Honorable Edmund G. Brown, Governor
and Members of the Legislature
of the State of California
State Capitol
Sacramento, California

Gentlemen:

Bulletin No. 96, entitled "Southern Tuolumne County Investigation," culminates an investigation that was conducted under terms of a cooperative agreement between the State of California and the Board of Supervisors of Tuolumne County. The objective of the Southern Tuolumne County Investigation was to formulate a plan for water development in that portion of Tuolumne County lying generally south of the Tuolumne River and west of Yosemite National Park.

As a result of this investigation, it has been determined that the Middle Fork Tuolumne River, South Fork Tuolumne River, and Big Creek provide the most favorable possibilities for local water development. A recommended project that was found to have economic justification and that could meet initial water requirements of Southern Tuolumne County is presented in this bulletin. The need for additional development to meet further water requirements is also discussed.

All concerned public and private agencies, as well as local interests and individuals, are invited to submit their comments on the information presented herein.

Sincerely yours,

William E. Warne

Director

State of California
The Resources Agency
Department of Water Resources

EDMUND G. BROWN, Governor
HUGO FISHER, Administrator, The Resources Agency
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was conducted under the direction
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ACKNOWLEDGMENT

Valuable assistance and data used in this investigation were contributed by agencies of the state and federal governments, Tuolumne County, public districts, private companies, and individuals. Their cooperation is hereby gratefully acknowledged.

Special mention is made of the cooperation extended by:

Tuolumne County Water District No. 2

California Department of Fish and Game, Region IV

Stanislaus National Forest Headquarters

Farm Advisor and the Agricultural Commissioner of Tuolumne County

Pacific Gas and Electric Company

City and County of San Francisco

Oakdale Irrigation District

South San Joaquin Irrigation District

Modesto Irrigation District

Turlock Irrigation District

Waterford Irrigation District

Tuolumne County Assessor

CHAPTER I. PURPOSE AND AREA OF THE INVESTIGATION

This chapter discusses the background of this investigation, briefly describes the objectives of the investigation, takes note of related investigations, and then describes the area of the present investigation. The description touches upon natural features, geology, climate, soils, and development.

Background of Investigation

The present economy of Southern Tuolumne County is static. Why? Because the county needs water that can be made available to prospective users.

The present economic base of the area is recreation, agriculture, and lumbering. Since there is a scarcity of timbered land available for development in Southern Tuolumne County, lumbering is a limited source of income to the area, and will probably continue to be so.

Future economic growth in the area, therefore, must depend upon an increase in recreational and agricultural activities and upon the establishment of new industrial enterprises. The greatest potential for economic growth probably lies in recreation. Such economic growth would be dependent upon development of low-cost water. Although no concerted area-wide drive for water development in the Groveland area has occurred in the past, the people of the area are now actively investigating the possibilities for a more adequate water supply.

The Board of Supervisors of Tuolumne County, having noted that future water requirements of Southern Tuolumne County could be met only by new developments on the Tuolumne River,

recognized that a comprehensive investigation of the water resources and needs of the Southern Tuolumne County area was necessary. Consequently, steps were taken in 1957 to request that the Department of Water Resources undertake such an investigation.

Just a few months before the Board of Supervisors of Tuolumne County had determined the need for a study of the southern Tuolumne area, the Board of Directors of Tuolumne County Water District No. 2 determined that there was a need for a similar study for Tuolumne County Water District No. 2 and similar arrangements were made with the Department of Water Resources. Results of that investigation are reported upon in a companion volumne, Bulletin No. 95, entitled "Tuolumne County Water District No. 2 Investigation."

Authorization for Investigation

The Board of Supervisors of Tuolumne County, in February 1958, requested by Resolution No. 41 that the Department of Water Resources make a preliminary investigation and report on the scope and cost of a cooperative water resource investigation of that portion of Tuolumne County outside of Tuolumne County Water Districts Nos. 1 and 2. A copy of this resolution is included in Appendix A, "Agreement Between the State of California Department of Water Resources and Tuolumne County."

The preliminary investigation was conducted and reported on in "Preliminary Report on the Water Resources and Water Problems in Southern Tuolumne County," dated June 1958. The preliminary

report presented recommendations for a comprehensive two-year investigation of Southern Tuolumne County area at a total cost of $36,000. Of this amount, it was recommended that the county and the State provide funds equally in the amount of $18,000.

The Board of Supervisors of Tuolumne County concurred with the need for a two-year cooperative investigation to be financed as recommended in the preliminary report and authorized the negotiation of an agreement. This agreement, a copy of which is included in Appendix A, was entered into as of July 1, 1958, but it did not become effective until December 1958 when the county's share of the costs of the investigation was received.

The department included funds in its 1958-59 and 1959-60 budgets for the State's portion of the cost of the investigation.

Objective of Investigation

The objective of the Southern Tuolumne County Investigation was the formulation of plans for the development of water supplies for all beneficial uses within the area.

Field work and office studies for the investigation commenced in December 1958, and continued into the spring of 1961. Plans were formulated for the development of water supplies for all beneficial uses within Southern Tuolumne County. These plans considered the conservation of water for irrigation, domestic, recreation, fish, and wildlife purposes and for production of hydroelectric power. Water conservation projects considered to have possibilities for development

in the immediate future were evaluated with respect to engineering feasibility and economic justification.

Related Investigations

The Southern Tuolumne County Investigation included review of several prior investigations and reports. Of major importance are the following two recent investigations and related reports of the Department of Water Resources.

Statewide Water Resources Investigation

The California Legislature in 1947 amended the Water Resources Law of 1945 to authorize the Department of Water Resources, and its predecessor agency, to conduct a comprehensive investigation of the water resources throughout the State of California. (Calif. Stats. 1945, Ch. 1514, P. 2830; as amended by Calif. Stats. 1947, Ch. 908; Water Code Sec. 12616.) This investigation was conducted by the Division of Water Resources, under the direction of the State Water Resources Board. Funds were appropriated annually by the Legislature over a 10-year period for the completion of this important program of study. Results of the investigation were published in three bulletins.

> Bulletin No. 1, "Water Resources of California," published in 1951, contains a compilation of data on precipitation, unimpaired streamflow, flood flows and frequencies, and quality of water.
>
> Bulletin No. 2, "Water Utilization and Requirements of California," published in 1955, sets forth estimates of present and probable ultimate water requirements throughout the State. In general, such estimates and forecasts are based on the capabilities of the land to support further development.

Bulletin No. 3, "The California Water Plan," published in 1957 reports the third and concluding phase of the State-Wide Water Resources Investigation. The California Water Plan is a comprehensive master plan for the development of the water resources of the State to meet, so far as is practicable, present and future needs for all beneficial purposes in all parts of the State.

The Legislature adopted "The California Water Plan" as a general guide for the orderly and coordinated development and use of the water resources of the State in 1959 (Calif. Stats. 1959, Ch. 2053; Water Code Secs. 10004-10007).

Survey of Mountainous Areas

The Survey of Mountainous Areas was initiated in 1946 and involved an evaluation of potential ultimate water needs for all or parts of 13 counties. The area of investigation, which included all of Tuolumne County, is located in foothill and mountainous areas on the westerly slope of the Sierra Nevada. A report on the investigation was published in 1955 as Bulletin No. 56, "Survey of Mountainous Areas."

The investigation reported upon in this report, as well as companion studies reported upon in Bulletin No. 95, "Tuolumne County Water District No. 2 Investigation," is an extension of the survey of mountainous areas.

Area of Investigation

Tuolumne County is located in a foothill and mountainous area on the westerly slope of the central Sierra Nevada, directly east of San Francisco Bay. It ranges in elevation from about 300 feet in the foothill area of the southwestern portion of the

county to over 13,000 feet at the crest of the Sierra Nevada. Except for the foothill areas, most of the county is within Stanislaus National Forest, Yosemite National Park, or Emigrant Basin Primitive Area. The Southern Tuolumne County area is that portion of Tuolumne County south of Tuolumne County Water District No. 2, and west of Yosemite National Park. Of the 1,462,900 acres of the county, about 172,600 acres are within the Southern Tuolumne County area, 427,800 acres are within Yosemite National Park, and 862,500 acres are within Tuolumne County Water District No. 2. Plate 1, entitled "Area of Investigation," delineates the county boundaries as well as those of the Southern Tuolumne County area.

Natural Features

The general lay of the land in Southern Tuolumne County could be described as a plane sloping on a gentle 2-degree slope starting at an elevation of about 300 feet at La Grange Reservoir and rising to elevations of about 6,000 feet near the western boundary of Yosemite Park. This plane is dissected by streams which become progressively less intrenched as they flow to the west. The plane is further modified by local relief which varies from moderate foothills in the lower portions to more rugged slopes in the higher portion. Between these extremes lie areas of moderately rolling lands marked with small alluvial plains along local creeks. In these rolling lands open grasslands are surrounded by extended areas of brush and oak trees. Modest tracts of merchantable timber are found in the easterly portions of the area.

Tuolumne County is drained by portions of the Tuolumne River and the Stanislaus River systems. Plate 1 depicts the relationship of the two river systems to the Southern Tuolumne County area. Both river systems are deeply intrenched, with narrow flood plains along their upper reaches and increasingly broader flood plains along their lower reaches. The Southern Tuolumne County area generally lies south of the main stem of the Tuolumne River and is entirely within the Tuolumne River Basin.

Geology

Southern Tuolumne County is situated on the gently dipping westward slope of the Sierra Nevada geomorphic province. This province is approximately 430 miles long and varies from 40 to 80 miles in width. It has been described as an immense, tilted fault block which ranges in elevation from near sea level along its western edge to a maximum height of 14,496 feet at Mount Whitney. In cross section, the Sierra Nevada has a gentle westward slope and an abrupt eastern scarp.

Two subdivisions of the Sierra Nevada geomorphic province are represented in the investigational area: (1) a low elevation or foothill province largely composed of metamorphic rocks, and (2) the High Sierra province principally composed of granitic rocks. The geologic provinces and their formations are discussed and illustrated in Appendix B, "Regional Geology."

The foothill province is confined to the western three-quarters of this investigational area. Here, metamorphic rocks

form a relatively broad northwest-trending belt of tight folds. Locally, Mesozoic igneous rocks intruded these folds. The folds are capped locally by mid- and late-Tertiary volcanic rocks. A northwest-trending foothill fault system cuts through the foothills. The fault system varies in width from less than 1 mile to over 3 miles along its 120-mile length. Quartz veins and the Mother Lode mineral deposits are associated with this fault system.

The High Sierra province covers the eastern one quarter of the area. It is underlain primarily by the granitic intrusive complex, but also includes small remnants of older metamorphic rocks which occur as "roof pendants." Tertiary volcanic rocks locally blanket the bedrock complex. During the Pleistocene epoch, snow and ice accumulated in the higher mountains and formed many slow-moving glaciers. These glaciers greatly modified the topography by depositing moraines and by cutting huge U-shaped valleys such as Yosemite Valley. At the present time, several small glaciers still exist in the high mountain area east of Yosemite Valley.

Climate

Because of ranges in elevation within the Southern Tuolumne County area, precipitation and temperature vary greatly. The mean seasonal depth of precipitation varies from about 18 inches in the lower foothill areas, to 35 inches in the Groveland area, and to about 55 inches in the higher portions of the area. The foothill areas experience hot, dry summers and mild winters.

The remainder of Southern Tuolumne County is characterized by moderate summers and colder winters.

Practically all precipitation occurs during the months of October through April. Variations in climate cause considerable differences in the length of the growing season within the county. Within the agricultural zone, the growing season varies from about 135 days in the upper areas to 255 days in the lower areas. The length of growing season in the Groveland area is estimated to be 200 days.

Soils

The soils of Southern Tuolumne County can be segregated into two broad categories. The first is that of recent alluvial soils. Those recent alluvial soils suitable for agriculture, while not significant from an acreage standpoint, have a wide crop adaptability because subsoil layers do not restrict the movement of water or the penetration of plant roots.

Upland soils represent the second category of soils in the area. These soils were formed in place by the weathering and decomposition of the underlying rock material. Such soils are important because they exist where practically all future agricultural development will take place. In general, as elevation and precipitation increase, the upland soils have an increasingly deeper profile and less rockiness. Shallow soil profiles and extreme rockiness, for example, are found in the lower western portions of the area while deep and nearly rock-free soils are found in the more easterly portions of the area.

Crop adaptability of the upland soils is largely restricted to the production either of irrigated pasture or of various types of deciduous orchard. Orchard crops are restricted to those areas having adequate air movement and deep, well-drained soil profiles. Many of the shallow and rocky soils found in the lower westerly portions of the county may prove to be marginal, even for the production of pasture, because of low moisture retention, low fertility, and resultant low crop yield.

Development

Tuolumne County was organized in 1850. In April 1854, the county was reduced in size when Stanislaus County was created from a portion of the original area of Tuolumne County. The major initial impetus for development of the area occurred when gold was discovered at New Jamestown in 1848 and in Columbia in 1850. As a result of mining activities connected with these discoveries, several communities were established and the population of the county increased to about 16,000 by 1860. Several water supply systems to supply these communities were developed. Remnants of some of these systems are in evidence today.

In more recent times, water development activities within Southern Tuolumne County have been mainly for the purpose of supplying water to areas outside the county. The Modesto and Turlock Irrigation Districts completed La Grange Dam and diversion facilities in 1894, and by 1901 the districts had completed their distribution systems and were diverting water from the Tuolumne River at La Grange Dam. Don Pedro Dam and Reservoir, also

comprising a cooperative project of Modesto and Turlock Irrigation Districts, were completed in 1923 as a multiple-purpose project, including conservation storage, power production, and flood control. Present diversion facilities at La Grange Dam have a combined capacity of about 4,500 second-feet. Furthermore, the City and County of San Francisco have developed the famous Hetch Hetchy System, including Hetch Hetchy, Lake Eleanor, and Lake Lloyd Reservoirs, to provide a water supply for use in San Francisco and vicinity, and also for the production of power.

Recreation is the major industry in the area. In addition to recreation, the major sources of income within the area are production of hydroelectric energy, lumbering, and agriculture. The hydroelectric power developments include development of the waters of the main Tuolumne River and Cherry and Eleanor Creeks. A number of organizational camps provide a major portion of the recreational opportunities within the area. Also of importance for recreational purposes are the public camp sites located in Stanislaus National Forest.

The principal areas that would derive benefits from the development of water for consumptive use are the potential urban and suburban lands in the Groveland-Big Oak Flat area.

State highways provide the principal road system. State Sign Route 120 extends easterly through the area to enter Yosemite National Park and crosses the Sierra Nevada at Tioga Pass. State Sign Route 49, the Mother Lode Highway, cuts across the area in a north-south direction. In addition to the state system, there are many miles of county roads and forest service roads.

CHAPTER II. WATER SUPPLY

Preparation of plans for the development of water supplies in Southern Tuolumne County required that the water resources of the Tuolumne River Basin be inventoried. This chapter discusses precipitation and runoff as they affect the area and describes the methods used to estimate natural runoff from recorded runoff. The chapter touches briefly upon present exports of water from the Tuolumne River Basin. It then discusses ground water and the quality of surface and ground water in the area.

The water supply of Southern Tuolumne County originates as direct precipitation in the form of rain or snow on the lands of the Tuolumne River Basin. A portion of this supply is used within the area under investigation, but most of it drains from the area by way of the Tuolumne River, or is retained in storage reservoirs for use outside the Southern Tuolumne County area. Modesto and Turlock Irrigation Districts, on the floor of the San Joaquin Valley, operate Don Pedro Reservoir, a multiple-purpose storage reservoir. In addition, the City and County of San Francisco have extensively developed the waters of the Tuolumne River Basin for export to San Francisco and portions of San Mateo, Santa Clara, and Alameda Counties.

Melting snow from the mountainous parts of the area provides the major portion of the seasonal runoff which occurs in the late spring and early summer months. By late summer, the streams have reached annual minimums and are sustained by springs

and effluent seepage. The resulting annual runoff pattern is one of peak flows in the winter and spring months, and low flows during the late summer months.

A 50-year mean period was selected to represent long-term runoff and precipitation characteristics in Southern Tuolumne County. The 50-year mean period used for the study of runoff extends from October 1, 1907, through September 30, 1957. The period used for the study of precipitation extends from July 1, 1905, through June 30, 1955.

For the purpose of the Southern Tuolumne County Investigation, the 35-year period from October 1, 1920, through September 30, 1955, was employed as a base period for detailed analyses of the hydrology of the Tuolumne River Basin. This base runoff period was selected because:

- Precipitation and streamflow data were sufficiently complete to enable extrapolation of the existing runoff records back to the 1920-21 runoff year* by correlation with records of comparable nearby stations having records for the desired period.

- Streamflow during the base period averaged about 96 percent of the flow of the 50-year mean period.

- The base period includes the critically dry period, extending from runoff year 1928-29 through runoff year 1934-35, during which the annual runoff was only about 60 percent of the runoff for the mean period.

- Other conditions of water supply and climate approximated mean conditions.

Precipitation

Southern Tuolumne County lies within the area traversed by the southern portion of storms which periodically sweep in from

*A runoff year extends from October 1 through September 30.

the North Pacific Ocean during winter and spring months. Precipitation resulting from these storms is generally light in the lower foothill areas and moderately heavy near the crest of the Sierra Nevada. Pronounced changes in elevation and topography have marked effects on the amount of precipitation and on whether it falls as rain or snow. Precipitation ranges from about 18 inches at lower elevations to about 55 inches at higher elevations.

Precipitation Stations and Records

There are 19 known precipitation stations located in or adjacent to the Southern Tuolumne area with unbroken records of 10 years or longer. Moreover, data are available for five stations with lesser periods of records. These stations are not well distributed areally in that there is only one station located above an elevation of 5,000 feet and that station has records extending back only to 1949. The longest period of record of precipitation in Tuolumne County is available for the Sonora station. This record is continuous since the precipitation year* of 1887-88. The longest continuous precipitation record in Southern Tuolumne County is found at Hetch Hetchy Reservoir. This record started in 1910.

Twenty snow courses lie in the Tuolumne River Basin. Such courses are measured and maintained as part of the California Cooperative Snow Surveys. All of these courses are at or above an elevation of 6,500 feet. Measurements at these courses provide important precipitation data for the uplands of the Tuolumne River Basin.

*A precipitation year extends from July 1 through June 30.

Table 1, entitled "Mean, Maximum, and Minimum Annual Precipitation At Selected Stations In or Near Southern Tuolumne County," presents the elevations, periods and sources of record, and mean, maximum, and minimum annual precipitation for the precipitation stations. Table 2, entitled "Snow Courses Within Tuolumne River Basin," presents similar information for the snow courses. In those instances when it was found necessary, precipitation records were extended to cover the 50-year mean period by direct correlation with records of nearby stations covering that period.

The records of precipitation at most stations and snow courses in or near Southern Tuolumne County have been published in reports of the United States Weather Bureau and the Department of Water Resources. Plate 2, entitled "Lines of Equal Mean Annual Precipitation," shows the locations of selected precipitation stations and snow courses and the lines of mean annual precipitation.

Precipitation Characteristics

Precipitation in Tuolumne County varies between wide limits from year to year and increases generally from west to east with an increase in land elevations. Winter storms deposit relatively light precipitation in crossing the floor of the San Joaquin Valley. However, the rate of precipitation increases sharply as the storms move toward the Sierra Nevada. Precipitation below an elevation of about 3,500 feet generally occurs in the form of rain and results in almost immediate runoff. Above

TABLE 1

MEAN, MAXIMUM, AND MINIMUM ANNUAL PRECIPITATION
AT SELECTED STATIONS IN OR NEAR SOUTHERN TUOLUMNE COUNTY

Station	County	Elevation in feet	Period of record	Source of record *	Mean annual precipitation, in inches	Maximum and minimum annual precipitation	
						Year	Inches
Confidence Hiatt	Tuolumne	4,000	1930-1933	private	43.64	1931-32 1930-31	53.73 25.83
Coulterville	Mariposa	1,660	1899-1902	private	24.14	--	--
Coulterville	Mariposa	1,070	1959-present	CDF	--	--	--
Crocker Station	Tuolumne	4,400	1857-1910 1948-52	USWB	48.71	1905-06 1897-98	89.54 31.37
Don Pedro Reservoir	Tuolumne	700	1940-present	SFPUC	20.24	1957-58 1958-59	29.10 11.58
Dudleys	Mariposa	3,000	1909-present	USWB	38.05	1910-11 1923-24	57.18 18.41
Early Intake Powerhouse	Tuolumne	2,356	1925-present	SFPUC	32.12	1937-38 1958-59	52.29 19.97
Exchequer Reservoir	Mariposa	484	1935-present	USWB	20.75	1955-56 1958-59	29.66 10.66
Groveland	Tuolumne	2,828	1930-1954	USWB	35.05	1937-38 1930-31	57.64 20.76
Groveland	Tuolumne	2,825	1940-present	USWB	35.05	1951-52 1958-59	50.09 24.70
Groveland Ranger Sta.	Tuolumne	3,135	1940-present	USWB	36.78	1955-56 1958-59	52.94 24.70
Hetch Hetchy	Tuolumne	3,670	1910-present	USWB	34.91	1937-38 1923-24	55.62 17.03
Jacksonville	Tuolumne	700	1908-1917	USWB	26.44	1910-11 1907-08	38.28 15.21
Jamestown	Tuolumne	1,471	1904-1915	USWB	31.04	1906-07 1912-13	48.49 17.49
Lake Eleanor	Tuolumne	4,662	1911-present	USWB	42.54	1937-38 1958-59	64.61 21.00
La Grange	Stanislaus	300	1869-1900 1909-32	USWB	16.64	1889-90 1876-77	30.24 5.74
Mariposa	Mariposa	2,011	1909-present	USWB	29.33	1910-11 1930-31	46.81 16.66
Mather	Tuolumne	4,518	1931-33 1955-present	USWB	33.87	1955-56 1930-31	45.90 24.44
Mocoasin	Tuolumne	950	1936-present	SFPUC	27.04	1937-38 1946-47	41.20 18.71
Phoenix Dam	Tuolumne	2,500	1909-1916	USWB	26.79	1913-14 1911-12	35.58 14.34
Priest	Tuolumne	2,245	1930-present	SFPUC	26.90	1957-58 1930-31	42.47 16.57
Sonora	Tuolumne	1,830	1888-present	USWB	31.31	1889-90 1923-24	67.29 13.67
Tuolumne	Tuolumne	8,600	1949-present	USWB	32.08	1951-52 1954-55	47.33 25.65
Yosemite National Park	Mariposa	3,985	1907-present	USWB	35.92	1937-38 1923-24	58.64 14.77

*USWB = United States Weather Bureau
SFPUC = San Francisco Public Utility Commission
CDF = California Division of Forestry

TABLE 2

SNOW COURSES WITHIN THE TUOLUMNE RIVER BASIN

Snow course	Latitude and longitude	Elevation, feet	Period of record	Water content of snow on April 1		
				1930-59 average, ins.	Maximum and minimum	
					Year	Inches
Fletcher Lake	37°47.8' 119°20.6'	10,300	1930-present	34.0	1952 1931	60.3 12.9
Tioga Pass	37°55.2' 119°15.2'	9,900	1926-present	27.3	1952 1931	40.6 8.4
Dana Meadows	37°53.0' 119°16.3'	9,700	1926-present	30.2	1952 1931	45.6 13.1
Rafferty Meadows	37°51.1' 119°19.3'	9,600	1948-present	31.0	1952 1959	48.3 20.1
Bond Pass	38°10.7' 119°37.4'	9,300	1948-present	44.1	1952 1948	73.5 23.0
Grace Meadow	38°09.0' 119°37.0'	8,900	1947-present	38.9	1952 1948	70.9 22.3
Snow Flat	37°49.6' 119°29.8'	8,700	1930-present	42.8	1952 1934	78.1 18.2
Tuolumne Meadows	37°52.7' 119°21.5'	8,600	1930-present	22.3	1938 1934	44.9 1.0
Horse Meadow	38°09.5' 119°39.7'	8,400	1948-present	46.5	1952 1955	80.5 34.1
Wilmer Lake	38°05.0' 119°38.5'	8,000	1946-present	43.6	1952 1948	76.0 26.3
Sachso Springs	38°05.1' 119°50.2'	7,900	1948-present	39.5	1952 1951	77.7 17.7
Spotted Fawn	38°05.5' 119°45.5'	7,800	1948-present	47.2	1952 1951	82.5 29.6
Huckleberry Lake	38°06.1' 119°44.7'	7,800	1948-present	43.2	1952 1951	76.1 24.7
Paradise	38°02.6' 119°40.0'	7,700	1946-present	41.4	1952 1951	80.6 21.9
Gin Flat	37°45.9' 119°46.4'	7,100	1930-present	35.3	1952 1934	75.2 13.3
Lower Kibbie Ridge	38°02.7' 119°52.6'	6,700	1937-present	27.6	1952 1947	66.6 9.3
Upper Kibbie Ridge	38°02.6' 119°52.8'	6,700	1937-present	21.2	1952 1947	57.1 1.0
Vernon Lake	38°01.0' 119°43.0'	6,700	1947-present	26.0	1952 1959	56.9 10.5
Beehive Meadow	37°59.7' 119°46.8'	6,500	1930-present	27.8	1952 1947	60.9 12.3
Bell Meadow	38°09.5' 119°56.5'	6,500	1937-present	19.7	1952 1951	58.2 2.6

this elevation, most precipitation occurs as snow; consequently, much of the resulting runoff is delayed until the period from April through July. A maximum mean annual rate of precipitation of about 55 inches occurs along the intermittently defined first crest of the Sierra. Between this area and the main crest, the precipitation is not noticeably affected by elevation. Here the average annual rate varies between about 45 and 60 inches.

The annual precipitation recorded at the Hetch Hetchy station has varied from about 49 percent to about 159 percent of the mean. The maximum annual precipitation of record at this station occurred in 1937-38 when a total of 55.62 inches was recorded. The minimum precipitation of record occurred in 1923-24 when a total of 17.03 inches was recorded. Approximately 67 percent of the yearly precipitation at Hetch Hetchy occurs during the period of December through March; less than 4 percent occurs from June through September. Long-term trends of precipitation on the Southern Tuolumne County area are indicated on Plate 3A, entitled "Recorded and Estimated Annual Precipitation at Hetch Hetchy," and Plate 3B, entitled "Accumulated Departure from Mean Annual Precipitation at Hetch Hetchy." Table 3, entitled "Average Monthly Distribution of Precipitation At Don Pedro Reservoir, Groveland, And Lake Eleanor," shows average monthly distribution of precipitation for three representative stations in or near the Southern Tuolumne County area. These three stations were selected to illustrate the monthly distribution of precipitation at different elevations.

The maximum recorded annual precipitation in the Southern Tuolumne area occurred at Crocker Station during the

TABLE 3

AVERAGE MONTHLY DISTRIBUTION OF PRECIPITATION
AT DON PEDRO RESERVOIR, GROVELAND, AND LAKE ELEANOR

Month	Precipitation, in inches and percent of annual total					
	Don Pedro Reservoir Elevation 700 feet		Groveland Elevation 2,848 feet		Lake Eleanor Elevation 4,662 feet	
	Inches	Percent	Inches	Percent	Inches	Percent
July	0.0	0.0	0.0	0.0	0.1	0.2
August	0.0	0.0	0.0	0.0	0.1	0.2
September	0.2	1.0	0.3	0.8	0.5	1.2
October	0.9	4.5	1.6	4.6	2.1	4.9
November	2.2	10.9	3.4	9.7	4.0	9.4
December	3.6	17.8	5.8	16.5	7.0	16.5
January	4.1	20.3	7.1	20.2	8.4	19.8
February	3.5	17.3	6.2	17.7	7.4	17.4
March	3.3	16.3	6.1	17.4	6.8	16.0
April	1.6	7.9	2.9	8.3	3.5	8.2
May	0.6	3.0	1.3	3.7	1.9	4.5
June	0.2	1.0	0.4	1.1	0.7	1.7
TOTALS	20.2	100.0	35.1	100.0	42.5	100.0

precipitation year of 1905-06 when a total of 83.54 inches was recorded. The maximum recorded snowpack in the Tuolumne River Basin occurred at the Spotted Fawn snow survey course in 1952 when a water content of 82.5 inches was measured. Because no single precipitation station is representative of the entire area, the stations at Don Pedro Reservoir, Groveland, and Lake Eleanor were selected to show annual amounts of precipitation. Annual precipitation recorded at these stations is presented in Table 4, entitled "Recorded Annual Precipitation At Selected Stations In Southern Tuolumne County."

Runoff

Surface runoff from the Tuolumne River system constitutes the only significant source of water supply available to Southern Tuolumne County. Use of this supply within the area, primarily from direct diversion of unregulated streamflow, is made for irrigation and domestic purposes. As previously stated, irrigation districts located on the floor of the San Joaquin Valley and the City and County of San Francisco have extensively developed the waters of the basin to produce hydroelectric energy and to furnish irrigation and municipal water supplies. Even with the present development, a portion of the runoff of the upper Tuolumne River Basin is unregulated and undeveloped and is a potential source of water to meet future requirements of the Southern Tuolumne County area.

TABLE 4

RECORDED ANNUAL PRECIPITATION AT SELECTED STATIONS IN SOUTHERN TUOLUMNE COUNTY
(In inches of depth)

Precipitation year	Don Pedro Reservoir	Groveland	Lake Eleanor
1910-11	-	-	59.35
12	-	-	25.43
13	-	-	27.27
14	-	-	55.16
15	-	-	43.92
1915-16	-	-	41.40
17	-	-	44.63
18	-	-	31.68
19	-	-	35.46
20	-	-	30.21
1920-21	-	-	40.81
22	-	-	36.72
23	-	-	40.08
24	-	-	20.83
25	-	-	48.15
1925-26	-	-	31.60
27	-	-	46.35
28	-	-	44.01
29	-	-	29.45
30	-	25.83	30.49
1930-31	-	20.76	29.99
32	-	40.75	54.14
33	-	21.58	32.34
34	-	24.98	28.70
35	-	43.36	54.99
1935-36	-	43.06	48.06
37	-	41.46	48.06
38	-	57.64	64.61
39	-	25.73	30.79
40	-	44.50	54.08
1940-41	24.74	46.04	55.16
42	22.74	42.40	52.16
43	20.12	42.71	53.85
44	16.92	32.68	36.74
45	22.97	40.54	48.82
1945-46	19.01	36.32	46.63
47	13.67	24.51	35.43
48	18.59	30.07	37.50
49	15.45	30.48	32.67
50	16.80	30.51	35.59
1950-51	23.35	39.03	58.37
52	27.20	48.82	59.67
53	17.15	27.33	36.32
54	16.37	30.59	42.29
55	15.28	25.52	30.48
1955-56	27.61	48.84	60.90
57	15.22	28.05	36.03
58	29.10	48.14	48.49
59	11.58	22.02	21.00
60	16.52	30.01	30.32

Stream Gaging Stations and Records

Records of streamflow for the Tuolumne River are generally sufficient in number, length, and reliability for purposes of hydrologic studies. Records of runoff were nonexistent, however, at most of the reservoir sites considered for potential water and power development. In order to estimate runoff at the reservoir sites, it was necessary to make correlations with nearby stations and/or to make area-precipitation comparisons of drainage areas.

Table 5, entitled "Stream Gaging Stations in the Tuolumne River Basin," presents the drainage areas, periods of record, and sources of record for stream gaging stations whose records pertain to the hydrology of the Tuolumne River Basin. Locations of the stations are shown on Plate 2, entitled "Lines of Equal Mean Annual Precipitation." Most of the runoff records for these stations have been published in United States Geological Survey Water Supply Papers or in Department of Water Resources bulletins.

Runoff Characteristics

Runoff from the Tuolumne River Basin is derived for the most part from melting snow. As a result, peak flows of the streams are reached in spring and early summer months, and low flows occur during late summer months. In addition to such fluctuations, runoff varies considerably from year to year. Such variation is caused primarily by widely fluctuating annual precipitation.

Continuous records of runoff in the Tuolumne River near La Grange have been maintained at several points since 1895. Prior to 1915, the flow was measured at La Grange Dam. Since 1915 the flow has been measured above La Grange Dam. Records at these

TABLE 5

STREAM GAGING STATIONS IN THE TUOLUMNE RIVER BASIN

Stream	Station	Drainage area, in sq. mi.	Periods of record	Source of record*
Falls Creek	near Hetch Hetchy	45	1915-present	USGS
Tuolumne River	at Hetch Hetchy Cabin	404	1910-1916	USGS
Tuolumne River	at Hetch Hetchy Dam Site	456	1910-1915	USGS
Tuolumne River	near Hetch Hetchy	462	1914-present	USGS
Tuolumne River	above Early Intake	--	1939-present	USGS
San Francisco Tunnel Diversion	near Hetch Hetchy	--	1932	SFPUC
Eleanor Creek	near Hetch Hetchy	80	1909-present	USGS
Cherry Creek	near Hetch Hetchy	111	1910-1955	USGS
Cherry Creek	below Cherry Valley Dam	118	1956-present	USGS
Cherry Creek Canal	near Early Intake	--	1956-present	USGS
Cherry Creek	near Early Intake	226	1956-present	USGS
Jawbone Creek	near Tuolumne	20	1910-1914	USGS
Cornal Creek	near roveland	--	1910-1913	USGS
Tuolumne River, Middle Fork	near Madher	52	1924-1929 1931-1933	USGS
Tuolumne River, Middle Fork	at Oakland Recreation Camp	71	1915-present	USGS
Tuolumne River, South Fork	at Italian Flat	67	1924-1930 1931-1933	USGS
Tuolumne River, South Fork	near Sequoia	70	1914-1918	USGS
Golden Rock Ditch	near Sequoia	--	1914-1915	USGS
Tuolumne River, South Fork	near Oakland Recreation Camp	88	1923-present	USGS
Tuolumne River, South Fork	near Buck Meadows	163	1910-1922	USGS
Tuolumne River	near Buck Meadows	934	1907-1909 1911-1936	USGS
Indian Creek	near Tuolumne	--	1910-1911	USGS
Clavey Creek	near Tuolumne	--	1910-1913	USGS
Clavey Creek	near Buck Meadows	140	1959-present	USGS
Big Creek	near Groveland	25	1931-1933 1959-present	USGS
Tuolumne River, North Fork	above Dyer Creek, near Tuolumne	--	1958-present	USGS
Tuolumne River, North Fork	near Tuolumne	--	1910-1911	USGS
Hunter Creek	near Tuolumne	--	1910-1913	USGS
Mocassin Powerplant Discharge	near Hetch Hetchy	--	1936-present	SFPUC
Tuolumne River	near Jacksonville	1,352	1923-1934	USGS
Woods Creek	near Jacksonville	98	1924-present	USGS
Tuolumne River	above La Grange Dam	1,534	1915-present	USGS
Sierra & San Francisco Power Company Canal	near La Grange	--	1908-1926	USGS
Modesto Canal	near La Grange	--	1903-present	USGS
Turlock Canal	near La Grange	--	1899-present	USGS
Tuolumne River	near La Grange	1,540	1895-1915	USGS
Tuolumne River	at La Grange Bridge	--	1937-present	DWR & TID

*USGS = United States Geological Survey
SFPUC = San Francisco Public Utilities Commission
DWR = Department of Water Resources
TID = Turlock Irrigation District

stations were equated by making minor revisions to the flows recorded at the early station to account for upstream diversions.

Variations in the runoff of the Tuolumne River near La Grange are illustrated by the following statistics. During the 35-year period 1920-21 through 1954-55 the estimated maximum natural runoff* was 3,424,000 acre-feet in 1937-38. The estimated minimum natural runoff in the 35-year period was 537,000 acre-feet in 1923-24. The estimated average annual natural runoff in the 35-year period was 1,724,000 acre-feet. The estimated annual natural runoff in the 50-year mean period 1907-08 through 1956-57 was 1,796,000 acre-feet.

The natural runoff of the Tuolumne River above La Grange Dam presently is impaired by major storage reservoirs and diversion facilities of the City and County of San Francisco and of the Modesto and Turlock Irrigation Districts.

Estimates of natural runoff were made in this basin to help evaluate potential water conservation projects. The method used to estimate the natural runoff of three of the more important stream gaging stations is herein described. Man-made impairments to the flow at each of these stream gaging stations are so small that the recorded flows were considered to be equivalent to natural

*Natural runoff is the flow of a stream as it would be if unaltered by upstream diversion, storage, import, export, or change in upstream consumptive use caused by development. Natural runoff is reconstructed from recorded runoff by allowing for the quantitative effect of alterations in streamflow above the point where the flow is measured. Natural runoff may be contrasted with impaired runoff. Impaired runoff is the flow of a stream as it would be under any given state of upstream development.

flows. To estimate the flows during periods when records were not available, correlations* were made as follows:

- Middle Fork Tuolumne River at Oakland Recreation Camp--flows have been recorded here since 1916 so no correlation was needed.

- South Fork Tuolumne River near Oakland Recreation Camp--correlations were made with the natural flow of the Middle Fork Tuolumne River at Oakland Recreation Camp.

- Big Creek near Groveland--correlations were made with the established natural flow of Woods Creek near Jacksonville and with precipitation at Groveland. The natural flows so derived are subject to some error in detail but probably are satisfactory for the purpose of this investigation.

Table 6, entitled "Estimated Annual Natural Runoff at Selected Locations in the Tuolumne River Basin," shows runoff for the base period. The table includes the runoff index** for the flow of the Tuolumne River near La Grange.

Annual natural runoff in the upper portion of the Tuolumne River Basin fluctuates less severely than does that in the lower portion of the basin. Maximum annual natural runoff of the Tuolumne River Basin above Hetch Hetchy Reservoir during the 35-year base period (1920-55) occurred in runoff year 1937-38 and was about 175 percent of the average. During the same year, maximum annual natural runoff in that part of the basin between Hetch Hetchy and Don Pedro Reservoirs was about 225 percent of the average. Minimum annual

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* In making correlations, consideration was given to precipitation, elevation, area, and orientation of the basin. The estimated annual runoff was then distributed to obtain monthly quantities, according to recorded runoff patterns of nearby streams having similar flow characteristics.

** The runoff index is the ratio of the amount of runoff during a given year to the mean annual amount of runoff.

TABLE 6

ESTIMATED ANNUAL NATURAL RUNOFF AT SELECTED LOCATIONS
IN THE TUOLUMNE RIVER BASIN

(In thousands of acre-feet)

Water year	Big Creek near Groveland	Cherry Creek near Hetch Hetchy	Tuolumne River near Hetch Hetchy	Middle Fork Tuolumne River at Oakland Recreation Park	South Fork Tuolumne River near Oakland Recreation Park	Tuolumne* River above La Grange	Runoff index, percent
1920-21	8	301	782	59	74	2,018	112
22	10	351	936	82	103	2,471	138
23	6	271	663	48	72	1,786	99
24	1	98	263	14	20	537	31
25	13	298	857	61	62	1,932	108
1925-26	3	184	518	34	39	1,110	62
27	10	305	885	61	76	2,051	114
28	6	223	617	44	50	1,525	85
29	3	155	467	27	32	969	54
30	3	199	536	26	30	1,146	64
1930-31	1	113	297	12	16	602	34
32	14	309	860	61	71	2,114	117
33	1	178	537	29	35	1,104	62
34	2	149	358	16	22	807	45
35	15	318	869	70	85	2,103	117
1935-36	15	306	878	67	76	2,160	120
37	13	271	797	66	88	1,997	111
38	32	453	1,275	133	185	3,424	191
39	2	160	435	26	38	981	55
40	16	335	846	61	84	2,207	123
1940-41	18	354	1,004	82	114	2,489	139
42	14	355	1,020	86	113	2,356	131
43	14	330	937	78	107	2,370	132
44	5	218	584	40	54	1,295	73
45	12	326	882	66	92	2,085	116
1945-46	8	294	811	68	80	1,874	104
47	2	180	538	31	41	1,094	61
48	5	234	670	40	45	1,408	78
49	4	214	565	34	42	1,246	69
50	4	266	708	42	47	1,545	86
1950-51	10	351	993	77	93	2,475	138
52	22	413	1,129	105	130	2,982	167
53	3	255	676	41	50	1,525	85
54	4	235	589	44	54	1,429	79
55	8	197	514	26	35	1,124	63
**	9	263	723	53	67	1,724	96
***	0.5	15.2	41.9	3.1	3.9	100	

*Summarized from estimates made by the City of San Francisco on a daily basis.
**Average for 35-year base period 1920-21 through 1954-55.
***Average annual flow measured as a percentage of the combined flow above La Grange Dam.

natural runoff of the Tuolumne River Basin during the base period occurred in water year 1923-24 and was about 36 percent of the average in the area above Hetch Hetchy Reservoir and about 24 percent of the average for the area between Hetch Hetchy and Don Pedro Reservoirs.

Natural runoff estimates above La Grange Dam have been computed by this department and by the City and County of San Francisco for the period from 1896 to present. An annual summary of natural runoff of the Tuolumne River above La Grange Dam is shown graphically on Plate 4A, entitled "Estimated Annual Natural Runoff of Tuolumne River above La Grange Dam." Long-term trends in natural runoff of the Tuolumne River near La Grange are indicated on Plate 4B, entitled "Accumulated Departure from Mean Annual Natural Runoff of Tuolumne River above La Grange Dam."

Exported Water

Water is exported from the Tuolumne River Basin above Don Pedro Reservoir by the Hetch Hetchy System of San Francisco. This water is conveyed through more than 150 miles of tunnel and pipeline to the service area in San Francisco and its vicinity. Recent deliveries through this system average about 167,000 acre-feet annually. This amount, according to estimates of the City of San Francisco, is expected to increase to an ultimate demand of about 450,000 acre-feet per year.

Turlock, Modesto, and Waterford Irrigation Districts divert large quantities of water from La Grange Dam to the valley floor for irrigation purposes.

Imported Water

Small quantities of water are imported to the Tuolumne River Basin from the Stanislaus River Basin through the Pacific Gas and Electric Company's Tuolumne Ditch. An average of over 17,000 acre-feet per year has been recorded at the head of that conduit. Because a large portion of this water is used consumptively within Tuolumne County Water District No. 2, it is estimated that less than half of the recorded diversion adds to the runoff of the Tuolumne River at La Grange.

Ground Water

Ground water, by definition, refers only to that water which occurs within the zone of saturation in the open spaces that exist in most of the materials comprising the earth's surface. By this definition, ground water is found under the entire extent of the Southern Tuolumne area. Where the spaces in the rock comprise a relatively high percentage of the total volume and are interconnected, the rocks are called water-bearing because substantial amounts of water can be removed from them. If the open spaces in the rock constitute little of the total volume or are not interconnected, the rock will yield little water and is considered to be nonwater-bearing.

The water-bearing characteristics of the lands of the Southern Tuolumne area will be discussed while referring to Plate B-1 entitled "Regional Geology." All formations except the alluvium (Q_{al}), the glacial moraine (Q_m), the andesitic volcanic rocks ($T_V{}^a$), and the

auriferous gravels (T_g) are crystalline and therefore nonwater-bearing. Wells, when properly located, will drain the interconnected fractures and joints in these nonwater-bearing rocks and yield flows from 5 to 15 gallons per minute. In the fall months of water deficient years, these wells frequently fail. Such wells deliver nearly all the present domestic water supplies in the Groveland-Big Oak Flat area.

Alluvium (Q_{al}) does not exist in sufficient quantities to be considered as an aquifer in the Southern Tuolumne area. The andesitic volcanic rocks ($T_V{}^a$) located in Sections 30 and 31, Township 1 North, Range 17 East, and the glacial moraine (Q_m) near Mather are not located near potentially developable service areas and therefore were not studied further. Andesitic volcanic rocks ($T_V{}^a$) are also found near Smith Station, but because they outcrop on ridges and topographic highs and are therefore above the zone of saturation, these rocks are considered unimportant to ground water except as they serve to conduct percolating waters to the auriferous gravels under them. The auriferous gravels (T_g) located near Smith Station and to the northwest are then the only water-bearing rocks near a potential service area in the Southern Tuolumne area. Well production in this unit is somewhat variable. A well in Burch Meadow reportedly produces 200 gallons per minute with a drawdown of 40 feet. Other wells in this unit appear to produce water in comparable quantities. Until a detailed ground water inventory of this area is made, it is impossible to determine the volume of ground water storage available or the safe yield of these gravels.

Quality of Water

The surface waters of the Tuolumne River Basin are generally of excellent mineral quality and are well suited for all types of use. Ground waters of Southern Tuolumne County, except in certain areas, also are generally of excellent mineral quality and well suited for irrigation and other uses. Table 7, entitled "Mineral Analyses of Representative Surface Waters of the Tuolumne River Basin," shows mineral analyses of representative waters of the Tuolumne River Basin and indicates desirable limits of mineral concentrations in Class 1 irrigation water. The water quality standards discussed in this bulletin are those commonly employed by the Department of Water Resources in evaluating mineral quality of water relative to urban, suburban, irrigation, and fish and wildlife requirements. Such standards are merely guides to the appraisal of water quality. Except for those constituents which are considered toxic to human beings, these standards should be considered as suggested limiting values. A water which exceeds one or more of these limiting values need not be eliminated from consideration as a source of supply, but other sources of better quality water should be investigated.

Quality of Surface Water

Analyses of surface water samples collected in 1959 from the Tuolumne River Basin showed that the waters were of excellent mineral quality and were well suited for irrigation and other uses. In addition, the department has collected samples monthly from the Tuolumne River at Don Pedro Dam for the past five years as a part of the surface water quality monitoring program. Records of this program indicate that waters flowing in the Tuolumne River were

TABLE 7

MINERAL ANALYSES OF REPRESENTATIVE SURFACE WATERS OF THE TUOLUMNE RIVER BASIN

	Date of sample	Conductance at 25°C (EC x 10^6)	Mineral constituents, in parts per million								
			Boron	Calcium	Magnesium	Sodium	Bicarbonate plus carbonate	Chloride	Sulfate	Nitrate	Percent sodium
Hunter Creek near Tuolumne	6-16-59	108	0.07	14	1.4	4.2	56	2.5	1.0	0.6	17
North Fork Tuolumne River near Tuolumne	6-16-59	78	0.07	8.2	1.3	4.6	42	1.0	0.6	0.8	27
North Fork Tuolumne River Near Long Barn	6-15-59	69	0.10	7.2	1.2	4.0	38	1.5	0.0	0.9	25
Clavey River near Tuolumne	6-16-59	36	0.10	3.3	0.7	2.1	16	1.0	0.8	0.7	27
Tuolumne River at Lumsden Bridge	6-16-59	17	0.10	1.9	0.4	1.2	8	1.0	0.6	0.6	28
Arithmetic average of all samples		67	0.11	7.4	1.2	3.5	34	1.2	2.2	0.6	26

consistently of excellent quality. The waters were characterized by a very low content of total mineral solubles, chloride, and boron, and by a low percent of sodium. Analyses of surface water samples from minor tributary streams indicate that waters from these sources have a higher concentration of mineral solubles than waters from the main stem of the Tuolumne River, but are well within the allowable limits of Class 1 irrigation water. Class 1 irrigation water, as defined by the Department of Water Resources, is suitable under most conditions for most crops. Class 2 water is of doubtful suitability, under certain conditions, for crops of low salt tolerance including citrus, deciduous fruit, some vegetables, and most clover grasses. Class 3 water is ordinarily unsatisfactory for all crops except the more tolerant plants such as cotton, sugar beets, and salt-tolerant forage grasses.

The quality of surface water samples collected in 1959 also easily meets U. S. Public Health Standards for drinking water.

Waters of high quality are necessary for preservation and protection of fish and wildlife. High quality is required not only for the proper environment of fish but also for maintenance of naturally occurring food upon which fish depend for survival.

Quality of Ground Water

Samples of ground water were collected from selected springs and wells within Tuolumne County in 1959 for quality analysis. Since only a few samples were collected within the Southern Tuolumne area, and since ground water quality is probably relatively uniform throughout the county, all available ground water analyses in the county were used in the Southern Tuolumne area ground water study. The

mineral quality of water from wells and springs in the county was determined to be extremely well suited to irrigation uses. However, on the basis of suitability for domestic uses, water from some wells did not meet prescribed standards for mineral quality set by the U. S. Public Health Service. For example, water obtained from one well in the vicinity of Yosemite Junction was found to contain slightly more than the allowable limit of arsenic (0.05 parts per million). Other wells in the vicinity of Rawhide Flat and Groveland contain water with more than the recommended limits of the combination of iron and manganese (0.3 parts per million). A summary showing the arithmetic averages of the mineral constituents of all available ground water samples and comparisons with the allowable limits set for Class 1 water is presented in Table 8, entitled "Mineral Analyses of Ground Water from Representative Wells Within Tuolumne County."

TABLE 8

MINERAL ANALYSES OF GROUND WATER FROM REPRESENTATIVE WELLS WITHIN TUOLUMNE COUNTY

	Conductance, at 25°C (EC x 10^6)	Mineral constituents in parts per million: Boron	Calcium	Magnesium	Sodium	Bicarbonate + carbonate	Chloride	Sulphate	Nitrate	Percent sodium
Arithmetic average of 10 samples	501	0.11	45	28	18	259	12	30	9.0	14

CHAPTER III. LAND AND WATER USE

Predictions of the future extent of water use in Southern Tuolumne County underlie all proposals for the development of water for the area. Such predictions require the consideration of population trends, the classification of land as to possible use and the prediction of future land use. Once it is known how certain lands may be used, it becomes possible to say how much water that use will require.

This chapter discusses population trends and land and water use in Southern Tuolumne County. It describes methods by which predictions of future water requirements within the area are made.

Area Units

The Southern Tuolumne County area has been subdivided into three parts (units) to facilitate discussion of land and water use. The three units are delineated on Plate 5, entitled "Classification of Present and Potential Land Use." These three units are:

- Moccasin Unit
- Groveland Unit
- Harden Unit

The Moccasin Unit

The Moccasin Unit is bounded on the southeast and southwest by the Tuolumne County line, on the northwest by the Tuolumne River, and on the northeast by the northerly Moccasin Creek drainage boundary. This unit has a gross area of 57,080 acres.

The Groveland Unit

This unit is located in the middle portion of Southern Tuolumne County and is shaped roughly like a parallelogram. The unit is bounded on the north by the Tuolumne River, on the northeast

by Tuolumne River and Jawbone Ridge, on the southeast by the drainage divide of that portion of the Tuolumne River and the South Fork Tuolumne River above the confluence of those two streams, and on the south by the Tuolumne County line. The unit is bounded on the southwest by the Moccasin unit. This unit has a gross area of 43,780 acres.

The Harden Unit

The Harden Unit includes the remaining easterly one third of the Southern Tuolumne area and has a gross area of 71,760 acres.

Land Use

Predictions of the future extent of water use in Southern Tuolumne County depend, in part, upon estimates of future land use within the area. Therefore, a projection was made of long-term agricultural developments and adjustments; of municipal, recreational, and industrial developments; and of population growth. These projections were based on the following assumptions:

- Population will continue to grow, increase to an estimated 420 million in the United States, 56 million in California, 103,000 in Tuolumne County, and 9,600 in Southern Tuolumne County, by the year 2020.

- A relatively high level of employment and consumption will prevail during the period from the present to at least the year 2020.

- Price-cost relationships will resemble those of the period 1952-56, especially with respect to agricultural production and returns.

- The demand for land will continue to increase, since it is a scarce resource.

- With respect to the projected crops, the proposed service area may not have a competitive advantage with the other areas of the State; but the crops are the most advantageous for the area.

° Water of suitable quality will be available at a cost considered not unduly restrictive to irrigation development, except as specifically noted otherwise.

The last assumption proved upon further study to be incorrect. No project was found which could supply irrigation water at a cost within the estimated ability of the users to pay. Nevertheless, the derived water requirements for agricultural use under the above assumptions are of value and will be discussed further in this chapter. The effect of the inability to serve agricultural users should not significantly affect the projections for recreational, industrial, or municipal requirements.

Projection of Population

Predictions of the population in Southern Tuolumne County were made to provide a base for projecting land use and water use in the year 2020. Table 9, entitled "Present and Predicted Permanent Population Southern Tuolumne County," presents these predictions for urban, suburban, recreation, and rural population in the Harden, Groveland, and Moccasin Units.

The present population distribution was based upon a study of the results of the 1960 census. The year 2020 estimate of total Tuolumne County population was obtained from a previous departmental population study of California. The distribution of year 2020 population by type and by unit was estimated as part of this investigation by considering the classification of lands, the county-wide opportunity for employment, and by applying considerable judgment.

TABLE 9

PRESENT AND PREDICTED FUTURE PERMANENT POPULATION
SOUTHERN TUOLUMNE COUNTY

Population type	Harden Unit		Groveland Unit		Moccasin Unit		Area total	
	Present	Year 2020	Present	Year 2020	Present	Year 2020	Present	Year 2020
Urban	*	*	200	900	150	1,400	350	2,300
Suburban	*	*	110	1,900	100	400	210	2,300
Recreation	100	1,200	80	400	*	*	180	1,600
Rural	200	1,300	150	1,300	150	800	500	3,400
TOTAL	300	2,500	540	4,500	400	2,600	1,240	9,600

* Less than 50

Classification of Land

As an aid to land use predictions, lands in Southern Tuolumne County were segregated into six land use designations:

- Irrigable agricultural
- Irrigable forest and range
- Urban and suburban
- Recreation
- Park
- All others

Irrigable Agricultural Lands. Irrigable agricultural lands are classified according to slope and soil characteristics. Both slope and soil depth directly affect the degree of suitability of the lands for irrigation, and both remain relatively constant throughout extended periods of time. Consideration was not given to indirect economic factors related to crop production and marketing or to the location of a water supply because such factors vary with time. These latter factors are considered, however, in developing future patterns of land use.

Topographic conditions influence irrigation practices and crop adaptabilities, which in turn affect the amount of land that will ultimately be irrigated.

Topographic characteristics of irrigable agricultural lands are identified in the table of this bulletin by the following symbols:

V - These lands are level or slightly sloping and vary from smooth to hummocky or gently undulating relief. The maximum allowable slope is 6 percent for smooth, reasonably large-sized bodies lying in the same plane. As the relief increases and becomes more complex, lesser slopes become limiting. These lands are suitable for all climatically adapted crops.

H - These lands have greater slope and/or relief than those of the V class. They vary from smooth to moderately rolling or undulating relief. The maximum allowable slope is 20 percent for smooth, reasonably large-sized bodies lying in the same plane. As the relief increases and becomes more complex, lesser slopes become limiting.

M - These lands have greater slope and/or relief than those of the H class. They vary from smooth to steeply rolling or undulating relief. The maximum allowable slope is 30 percent for smooth, reasonably large-sized bodies lying in the same plane. As the relief increases and becomes more complex, lesser slopes become limiting.

Irrigable agricultural lands identified as V, H, or M, contain permeable soils with medium to deep effective root zones. They are free of rock and not limited by a high water table. Variations from this pattern are identified in the tables of this bulletin by the following subsymbols:

p - Shallow depth of effective root zone; land limited to shallow rooted crops.

r - Sufficient rock to restrict crop cultivation.

w - High water table; land limited to pasture crops unless drainage and a change in irrigation practice increase its adaptability to other types of crops.

Even in the most intensively developed areas of irrigated agriculture, all areas classified as irrigable agricultural lands would not receive water every year. The gross irrigable areas were therefore reduced for the following reasons:

- Farmers would limit production on lands having limited adaptability and productivity to periods when economic conditions were favorable.
- Crop rotation and fallowing would reduce the extent of irrigated land.
- Farmsteads, industries, and rights-of-way such as roads, railroads, and canals would occupy acreage.
- Certain nonirrigable lands occur within lands classified as irrigable because the area involved was too small to delineate.
- Small, irregularly shaped plots of land, isolated by ownership or location from larger units of irrigable land, would be irrigated less readily than the larger units.

Irrigable agricultural lands amount to 11,090 acres. Estimates indicate that about 24 percent, or 2,660 acres, of the gross irrigable agricultural lands would, for the above reasons, be devoted to non-agricultural uses. A net irrigable acreage of 8,430 acres would remain.

Irrigable Forest and Range Lands. These lands are presently forested or subjected to forest or range management. They possess the slope and soil characteristics of irrigable agricultural lands but, because of conditions of climate and location, are best suited to remain under some type of forest or range management program. The tables of this bulletin identify irrigable forest and range lands with the symbol "F."

Urban and Suburban Lands. These lands may be irrigable or nonirrigable. Irrigable lands classified as potential urban and

suburban lands possess the characteristics of irrigable agricultural lands (V, H, or M), but most likely will be used to absorb urban and suburban expansion brought about by the anticipated increase in population. Estimates of population in Southern Tuolumne County in the year 2020 (Table 9) were used to help determine the amount of land which was classified as potential urban and suburban land. The tables of this bulletin identify urban and suburban lands by the following symbols:

UD - Urban (city, town, small community) lands; presently developed for commerce, industry, and residences.

U - Potential urban (city, town, small community) lands; probable intense future development for commerce, industry and residences.

SR - Suburban and potential suburban lands; low density of residences; little or no commerce or industry.

The main purpose in the determination of U and SR lands was to indicate those irrigable lands of Southern Tuolumne County which urban encroachment would render unavailable for agriculture by the year 2020. Estimates of water use in U and SR lands by the year 2020 are based on predicted population rather than on area. SR lands subdivide into lands of high and low exterior water use. On the high exterior water use SR lands, it was assumed that most of the area that was not devoted to dwellings would be irrigated. On the low exterior water use lands, it was assumed that the water use would be confined to the dwelling and its landscaping.

Recreation Lands. These consist of lands presently or potentially characterized by fairly intensive recreation development requiring water service. The classification does not include those

high mountainous lands intensively used for recreation purposes by hunters and fishermen. Estimates of future population expansion (Table 9) and recognition of the increasing demand for recreation areas were considered in determining the acreage classified as potential recreation land. Estimates indicate that land so classified in Southern Tuolumne County will be used to only about half its full potential by the year 2020. Estimates of water use in recreation lands are based on predicted population rather than on area. Types of recreation lands are identified in the tables of this bulletin by the following symbols:

RR - Existing and potential permanent and summer home tracts.

RC - Existing and potential commercial areas (motels, resorts, hotels, stores, etc.).

RT - Existing and potential camp and trailer sites.

RR lands subdivide according to their probable density of development. For example, fewer houses per acre will be built on hilly land than on flat land. Calculations of the density of development of RR, RC, and RT lands provide a basis for predicting water use and requirements within Southern Tuolumne County in the year 2020.

Park Lands. These lands use little water and consist of existing county, state, and federal parks, race tracks, and fairgrounds. The tables of this bulletin identify park lands with the symbol "PP."

All Other Lands. These are identified in the tables of this bulletin by the symbol "N". The classification consists of all lands not included in one of the five previous designations. Table 10,

TABLE 10

CLASSIFICATION OF LANDS IN SOUTHERN TUOLUMNE COUNTY

(In acres)

Land classification	Unit			Total
	Harden	Groveland	Moccasin	
Irrigable agricultural lands				
V	80	--	--	80
Vw	390	--	--	390
Vp	10	--	70	80
H	--	2,730	120	2,850
Hp	--	60	1,120	1,180
Hr	--	60	130	190
Hpr	--	--	560	560
M	--	3,070	110	3,180
Mp	--	800	490	1,290
Mr	--	110	260	370
Mpr	--	--	920	920
Total irrigable agricultural lands	480	6,830	3,780	11,090
Urban and suburban lands				
UD (developed)	--	60	120	180
U (on irrigable lands)	--	--	100	100
U (on nonirrigable lands)	--	100	20	120
SR (on irrigable lands)	--	830	180	1,010
SR (on nonirrigable lands)	--	2,020	360	2,380
Total urban and suburban lands	--	3,010	780	3,790
Recreation lands				
RR (summer home tracts)	1,380	1,620	70	3,070
RC (commercial areas)	50	10	--	60
RT (camp and trailer sites)	1,290	210	220	1,720
Total recreation lands	2,720	1,840	290	4,850
Park lands				
PP	20	--	--	20
Irrigable forest and range lands				
F	9,720	1,470	730	11,920
All other lands				
N	58,820	30,630	51,500	140,950
TOTALS ALL LANDS	71,760	43,780	57,080	172,620

entitled "Classification of Lands in Southern Tuolumne County," shows all six designations and lists by units the acreage within each classification in Southern Tuolumne County.

Present and Future Land Use

Table 11, entitled "Present and Future Pattern of Land Use in Southern Tuolumne County," shows patterns of land use, in acres, at present and predicted patterns of land use for the year 2020. Plate 5, entitled "Classification of Present and Potential Land Use," depicts such land use within the Harden, Groveland, and Moccasin Units.

The predominant present use of land receiving water service within Southern Tuolumne County is for recreation purposes. Since the Groveland-Big Oak area is very close to the recreation opportunities offered in the Stanislaus National Forest and Yosemite National Park, the area is an attractive site for summer and retirement homes. Presently irrigated agricultural lands constitute less than 13 percent of the area currently receiving water service.

Predictions for the year 2020 indicate that if an adequate water supply is made available at a reasonable cost, the areas using water for agricultural, urban, and recreation purposes will expand to about 19 times their present size. Since no project was found to supply irrigation water at a cost within the ability of the users to pay, the use of land for irrigated agriculture will probably not be as great as that projected.

In summary, these predictions were developed by consideration of classification of lands and population forecasts. The classified

TABLE 11

PRESENT AND FUTURE PATTERN OF LAND USE IN SOUTHERN TUOLUMNE COUNTY

(Assumes an adequate supply of water at a price within ability of users to buy)

(In acres)

Land use	Harden Unit		Groveland Unit		Moccasin Unit		Area total	
	Present	Year 2020	Present	Year 2020	Present	Year 2020	Present	Year 2020
Areas receiving (present) or requiring (year 2020) water service								
Irrigated agricultural lands								
Improved pasture	--	100	70	2,800	--	800	70	3,700
Deciduous orchard	--	*	--	600	--	400	--	1,000
Miscellaneous (vineyards, truck and field crops, etc.)	--	*	--	*	--	100	--	100
Total irrigated agricultural lands	--	100	70	3,400	--	1,300	70	4,800
Urban and suburban lands	--	*	60	2,100	130	600	190	2,700
Recreation lands	270	1,900	30	1,300	--	100	300	3,300
Total area receiving water service	270	--	160	--	130	--	560	--
Total area requiring water service	--	2,000	--	6,800	--	2,000	--	10,800
Areas not receiving (present) or not requiring (year 2020) water service								
Irrigable agricultural lands								
Naturally irrigated meadow pasture (Vw)	400	400	30	*	--	*	430	400
Irrigable but devoted to other uses	--	*	50	3,400	--	2,500	50	5,900
Total irrigable agricultural lands	400	400	80	3,400	--	2,500	480	6,300
Park lands (PP)	20	20	--	--	--	--	20	20
Irrigable forest and range lands (F)	9,720	9,700	1,470	1,500	730	700	11,920	11,900
All other lands	61,350	59,640	42,070	32,080	56,220	51,880	159,640	143,600
Total area not receiving water service	71,490	--	43,620	--	56,950	--	172,060	--
Total area not requiring water service	--	69,760	--	36,980	--	55,080	--	161,820
TOTALS	71,760	71,760	43,780	43,780	57,080	57,080	172,620	172,620

* Less than 50 acres

lands were studied to determine their suitability for urban and suburban development, for recreation, and for irrigated agriculture. Population estimates were related to developable lands, and adjustments were made in the distribution of population and extent of development. Considerable judgment was applied during this process.

Water Use

Although the waters of the Tuolumne River Basin have been and are being developed for use in areas outside of Tuolumne County, water use within Southern Tuolumne County has remained relatively constant for several decades. The South Fork Tuolumne River could be developed to meet the future consumptive needs of Southern Tuolumne County, as well as nonconsumptive uses for recreation, hydroelectric power production, and fish and wildlife enhancement purposes.

At present, surface water diversions for use within Southern Tuolumne County average about 410 acre-feet annually. Urban, suburban, rural domestic, and recreation uses require about 160 acre-feet annually, and there is also an annual irrigation use of about 250 acre-feet. If water is made available to users at a cost within their ability to pay, it is estimated that the annual water requirement would increase to 17,800 acre-feet by the year 2020. Of the 17,800 acre-feet, 14 percent would be required for urban, suburban, rural domestic, and recreation purposes and the remaining 86 percent would be available for irrigation purposes. No project was found which would supply irrigation water at a cost within the ability of the users to pay; therefore, it was estimated

that the water delivery requirements for irrigation purposes would remain relatively constant. It is further estimated that the water requirement would increase only to 2,750 acre-feet annually by the year 2020. Of the 2,750 acre-feet, 2,500 acre-feet would be required for urban, suburban, rural domestic, and recreation purposes while the remaining 250 acre-feet would be required for irrigation purposes.

Existing Water Supply Developments

In this bulletin, predictions of the future extent of water use in Southern Tuolumne County underlie all proposals for the development of water. Such predictions rely, in part, upon estimates of present water use.

The principal supply of water for meeting present water delivery requirements within Southern Tuolumne County is ground water. Plate 9, entitled "Possible Features of Basin Plans for Water Development in the Tuolumne River Basin," shows present developments within the Tuolumne River Basin. Table 12, entitled "Dams Under the Jurisdiction of the State of California in or Adjacent to Southern Tuolumne County," lists pertinent statistics for those dams within the basin which come under state supervision. Table 13, entitled "Hydroelectric Power Plants in or Adjacent to Southern Tuolumne County," lists pertinent statistics for powerhouses located within the basin.

Water Delivery Requirements

A water delivery requirement is the amount of water needed to supply consumptive use plus all losses of water, both recoverable and irrecoverable, incidental to such use. Consumptive use refers to water used by vegetation for transpiration and for building of plant

TABLE 12

DAMS UNDER THE JURISDICTION OF THE STATE OF CALIFORNIA
IN OR ADJACENT TO SOUTHERN TUOLUMNE COUNTY

Name of dam	Owner	Stream	Location (MDB&M) Section	Township	Range	Type of dam	Crest length, in feet	Crest height, in feet	Elevation of crest above sea level	Maximum storage capacity acre-feet	Year completed	Use
Early Intake	City and County of San Francisco	Tuolumne River	11	1S	18E	Concrete arch	262	56	2,356	488	1925	Domestic, municipal, power
Lake Eleanor		Eleanor Creek	3	1N	19E	Multiple arch	1,260	61	4,661	27,800	1918	Domestic, municipal, power
Moccasin Lower		Moccasin Creek	34	1S	15E	Earth and rockfill	720	60	927	525	1930	Power, municipal
O'Shaughnessy		Tuolumne River	16	1N	20E	Concrete gravity	900	312	3,812	360,000	1923	Domestic, municipal, power
Priest		Rattlesnake Creek	31	1S	16E	Earth and rockfill	1,000	168	2,245	2,350	1923	Domestic, municipal, power
Cherry Valley		Cherry Creek	5	1N	19E	Earth and rockfill	2,630	315	4,715	268,000	1956	Domestic, municipal, power, irrigation
Don Pedro	Turlock and Modesto Irrigation Districts	Tuolumne River	35	2S	14E	Concrete gravity	1,040	278	609	289,000	1923	Irrigation, power
La Grange		Tuolumne River	16	3S	14E	Concrete gravity	280	131	294	500	1894	Irrigation

TABLE 13

HYDROELECTRIC POWERPLANTS IN OR ADJACENT TO SOUTHERN TUOLUMNE COUNTY

Name of powerhouse	Owner	Source of water		Location (MDB&M)			Installed capacity, in kilowatts	Maximum static head, in feet	Elevation of tailrace, in feet
		Stream(s)	Dam or Reservoir	Section	Township	Range			
Cherry	City and County of San Francisco	Eleanor and Cherry Creeks	Eleanor and Cherry Valley	35	1N	18E	135,000	2,481	2,219
Early Intake		Cherry Creek	Lake Eleanor	2	1S	18E	3,600	349	2,248
Moccasin		Tuolumne River	Early Intake & O'Shaughnessy	34	1S	15E	70,000	1,316	927
Don Pedro	Turlock and Modesto Irrigation Districts	Tuolumne River	Don Pedro	35	2S	14E	27,000	261	344
La Grange		Tuolumne River	La Grange	16	3S	14E	3,900	113	180

tissues, and to water evaporated from adjacent soil and from foliage. It also refers to water similarly consumed and evaporated by urban and nonvegetative types of land use. In addition to consideration of population (Table 9) and patterns of land use (Table 11), derivation of estimates of consumptive uses and water delivery requirements involve consideration of the following factors:

- Unit consumptive use of applied water
- Efficiency factors
- Unit delivery requirements.

Unit Consumptive Use of Applied Water. Unit consumptive use of applied water is a measure of the amount of water consumptively used in transportation and evaporation and is expressed either in gallons per capita per day or in acre-feet per acre per year.*

Efficiency Factors. Urban water use efficiency, expressed as a percentage, is the ratio of the urban unit consumptive use of delivered water to the urban unit delivery requirement. Similarly, farm irrigation efficiency is the ratio of the farm unit consumptive use of applied water to the farm unit delivery requirement. Urban water use efficiency percentages were used to convert unit consumptive use of delivered water into unit delivery requirements. Farm irrigation efficiency percentages were used to convert unit consumptive use of applied water into farm unit delivery requirements. Urban water use efficiency in Southern Tuolumne County is estimated to be about 50 percent; farm irrigation efficiency is estimated to be about 65 percent.

* A modification of a method developed by Harry F. Blaney and Wayne D. Criddle of the U.S. Soil Conservation Service was used to determine units of consumptive use for crops adequately irrigated under average weather conditions in Southern Tuolumne County.

Unit Delivery Requirements. Urban unit delivery requirements are measures of water delivery requirements for urban, suburban, and rural domestic uses, and for recreation. They are expressed in gallons per capita per day.*

Similarly, a farm unit delivery requirement is the amount of applied water with which an acre of land must be irrigated to meet the consumptive use requirement of the crop plus incidental losses. The farm unit delivery requirement is expressed in acre-feet per acre per year. Both urban and farm unit delivery requirements include water that will be lost to the areal unit under study, and they exclude that part of the consumptive use met by precipitation. In most instances, a portion of the water requirement necessary to supply consumptive use will return to the river and be available for diversion downstream.

Table 14, entitled "Present and Future Urban Unit Delivery Requirements and Unit Consumptive Use of Delivered Water in Southern Tuolumne County," shows present and future urban unit delivery requirements, and unit consumptive use of applied water in gallons per capita per day for rural domestic, urban, suburban, and recreation developments in Southern Tuolumne County.**

Table 15, entitled "Farm Unit Delivery Requirements and Unit Consumptive Use of Applied Water in Southern Tuolumne County," shows

* Studies of water deliveries in the Sonora, Twain Harte, and Lake Tahoe areas and in eight representative towns in both the Sierra Nevada and the Cascade Range contributed toward estimates of unit delivery requirements in Southern Tuolumne County.

** The increase in the average rate of water use per capita in such developments has continued throughout the past several decades and is expected to continue into the future. Estimates of future requirements are based on studies of such water use trends although it is recognized that past rates of increase do not form a completely satisfactory base for the projection of future water requirements.

TABLE 14

PRESENT AND FUTURE URBAN UNIT DELIVERY REQUIREMENTS AND UNIT CONSUMPTIVE USE OF DELIVERED WATER IN SOUTHERN TUOLUMNE COUNTY

(In gallons per capita per day)

Unit	Domestic use						Recreation use	
	Urban		Suburban		Rural			
	Present	2020	Present	2020	Present	2020	Present	2020
Urban unit delivery requirement	130	250	110	200	110	200	90	150
Unit consumptive use of delivered water	65	125	55	100	55	100	45	75

TABLE 15

FARM UNIT DELIVERY REQUIREMENTS AND UNIT CONSUMPTIVE USE OF APPLIED WATER IN SOUTHERN TUOLUMNE COUNTY

(In acre-feet per acre per year)

Unit	Crops			
	Alfalfa	Improved pasture	Deciduous orchard	Miscellaneous*
Farm unit delivery requirement	3.5	3.5	2.0	1.8
Unit consumptive use of applied water	2.3	2.3	1.3	1.2

* Vineyards, truck, field, and row crops, etc.

present and future farm unit delivery requirements and unit consumptive use of applied water in acre-feet per acre per year for irrigated agricultural lands in the area. The unit values of applied water and their corresponding efficiencies discussed in this bulletin are estimated annual averages.

Derivation of Consumptive Use and Water Delivery Requirements. The present and future consumptive use of applied water or associated water requirement is obtained by multiplying the appropriate unit consumptive use of applied water or unit delivery requirement by the area to be served.

Recreation lands in 2020 probably will be used to only half their estimated maximum potential. Estimated maximum water requirements for such lands therefore are double the requirements for the year 2020.

The expansion of urban and suburban lands beyond 2020 probably will continue to encroach on irrigated agricultural lands. Because such undetermined encroachments probably will require about the same amount of water per acre as the irrigated agricultural lands they replace, estimated maximum water delivery requirements of irrigated agricultural lands include estimated maximum domestic water delivery requirements of urban, suburban, and rural developments. The estimated maximum water delivery requirement of the area therefore equals the sum of year 2020 irrigation and domestic water requirements plus the product of acreage open to irrigation after 2020 and its farm unit delivery requirement plus twice the recreation water requirements of year 2020.

Table 16, entitled "Present and Future Water Uses, Consumptive and Delivery Requirements In Southern Tuolumne County," shows consumptive uses of applied water and water delivery requirements, present and future

TABLE 16

PRESENT AND FUTURE WATER USES, CONSUMPTIVE AND DELIVERY REQUIREMENTS
IN SOUTHERN TUOLUMNE COUNTY

(In acre-feet per year)

Unit	Irrigated agriculture				Domestic				Total
	Improved pasture	Deciduous orchard	Miscellaneous**	Sub total	Rural	Urban	Sub-urban	Recreation	
Harden									
Present consumptive use	-	-	-	-	10	-	-	-	10
Present deliveries	-	-	-	-	20	-	-	10	30
Year 2020 consumptive use	200	*	*	200	200	*	*	100	500
Year 2020 delivery requirement	300	*	*	300	300	*	*	200	800
Estimated ultimate delivery requirement	-	-	-	300	300	-	-	400	1,000
Groveland									
Present consumptive use	160	-	-	160	10	20	20	-	210
Present deliveries	250	-	-	250	20	30	20	-	320
Year 2020 consumptive use	6,400	800	*	7,200	100	100	400	*	7,800
Year 2020 delivery requirement	9,800	1,300	*	11,100	300	200	600	100	12,300
Estimated ultimate delivery requirement	-	-	-	19,200	300	200	600	200	20,500
Moccasin									
Present consumptive use	-	-	-	-	10	10	10	-	30
Present deliveries	-	-	-	-	20	20	20	-	60
Year 2020 consumptive use	1,900	500	200	2,600	100	200	200	*	3,100
Year 2020 delivery requirement	2,900	700	300	3,900	200	400	200	*	4,700
Estimated ultimate delivery requirement	-	-	-	8,200	200	400	200	-	9,000
Area total									
Present consumptive use	160	-	-	160	30	30	30	-	250
Present deliveries	250	-	-	250	60	50	40	10	410
Year 2020 consumptive use	8,500	1,300	200	10,000	400	300	600	100	11,400
Year 2020 delivery requirement	13,000	2,000	300	15,300	800	600	800	300	17,800
Estimated ultimate delivery requirement	-	-	-	27,700	800	600	800	600	30,500

* less than 50 acre-feet.

** Vineyards, truck, field and row crops, etc.

in acre-feet per year, if water were available at a cost within the ability of the users to pay. In this bulletin, such uses and requirements are estimated annual averages.

Nonconsumptive Water Use and Requirements. The use of water for hydroelectric power generation, fish and wildlife conservation, and recreation purposes in most instances does not affect the quantity or quality of the water. The water is used and then returned to natural channels. Such use, therefore, is nonconsumptive. Nonconsumptive water requirements and nonconsumptive water uses are considered to be equal when--as in most cases--the irrecoverable losses associated with the nonconsumptive use are negligible.

Whenever appropriate, Chapter V outlines specific nonconsumptive requirements for each segment of the projects proposed in this bulletin. A more general discussion of nonconsumptive requirements within the area follows.

Hydroelectric Power Generation. The use of water for generation of hydroelectric power is the principal nonconsumptive water requirement within Southern Tuolumne County and is an important factor in plans for the development and distribution of water within the area. Revenues from the sale of hydroelectric energy developed by water conservation works proposed in this bulletin might possibly be sufficient to reduce the cost of water used for other purposes.

Fish and Wildlife Conservation and Enhancement. Of considerable importance to the area and to the State as a whole is the preservation and enhancement of fish and wildlife. The intentional release of water from a storage reservoir to maintain certain minimum streamflows frequently detracts from the overall amount of water available for other project purposes such as hydroelectric power generation and water supply. Nevertheless, it is important that existing fisheries be maintained. Moreover, there are streams which are particularly suitable for recreation and for fish and wildlife, and which could be enhanced by the construction of minor upstream storage works to provide for improvement of low streamflow conditions.

The plans for water development within Southern Tuolumne County presented in this bulletin provide for maintenance flows. Although there might be some incidental enhancement of the fisheries of some of the streams, no benefits were claimed for such enhancement because the planned project operation schedule was developed on the basis of meeting hydroelectric power generation and other project needs, and during other periods only minimum releases required to maintain fisheries would be made.

Recreation Purposes. By virtue of its climatic advantages and variety of natural attractions, the area has outdoor recreation opportunities of great importance to the local economy and of significant importance to the State as a whole. With anticipated continued growth in population and an increasing interest in recreation, it is

expected that public demand for preservation and enhancement of recreation opportunities will be of sufficient importance to assure that these purposes will be considered in any water resource development project.

Water employed for boating, sailing, swimming, and other water sports is available naturally or is available from works constructed and operated for other purposes. The recreation potential of a reservoir can be improved by maintaining higher minimum water levels. This improvement was considered in planning water development in the area.

Additional Considerations

In addition to consideration of present and future water requirements, development of plans for reservoirs and irrigation canals requires consideration of the following factors:

- Conveyance losses of water
- Permissible deficiencies of water supply
- Monthly demands for water
- Flood control

Conveyance Losses of Water. Conveyance losses include evaporation, transpiration by vegetation, seepage, and wastage. Ways were developed during the present investigation to estimate these losses. Return flows from irrigated areas and domestic developments would be available for reuse, and were not deducted from the available water supply. Those losses not recoverable were treated as evaporation losses.

Permissible Deficiencies of Water Supply. Studies to determine deficiencies in the supply of irrigation water that might be endured without permanent injury to perennial crops were not made in connection with this investigation. It has been determined from prior investigations that in areas such as Southern Tuolumne County, a maximum deficiency of 35 percent of the full seasonal requirement can be endured if the deficiency occurs only at relatively infrequent intervals. Therefore, in reservoir operation studies, it was assumed that a deficiency of 35 percent could be endured in one year of the 35-year operational period. Smaller deficiencies would occur during less severe dry periods. The average seasonal deficiency during the operational period was limited to two percent. No deficiencies in urban water requirements were allowed at any time.

Monthly Demands for Water. A significant factor affecting the sizing of primary conveyance facilities is the monthly distribution of demands for irrigation water. These demands are seasonal in nature, being generally from April through October. The maximum rate of this demand within Southern Tuolumne County occurs during the month of August. On the other hand, the demand pattern for domestic water is continuous throughout the season with increases during the summer months for the watering of lawns and gardens. Recreation demands also show substantial increases during summer months. Monthly demands for water for generation of hydroelectric energy are similar to those for domestic water supplies. Table 17,

entitled "Monthly Demands For Water in Southern Tuolumne County," presents estimates of average monthly demands for water for each of these purposes.

TABLE 17

MONTHLY DEMANDS FOR WATER IN SOUTHERN TUOLUMNE COUNTY

(In percent of annual total)

Month	Hydroelectric power	Irrigated agriculture	Domestic Supply	Recreation use
January	6.1	0	5.4	1.4
February	5.3	0	5.3	1.6
March	6.9	0	5.4	1.8
April	7.6	1.0	6.0	2.3
May	8.0	5.2	7.2	12.1
June	10.3	14.9	10.1	20.3
July	12.9	24.1	13.8	23.7
August	12.9	24.1	13.8	23.7
September	9.1	20.6	12.5	7.2
October	7.6	11.3	8.7	3.2
November	6.5	1.5	6.2	1.3
December	6.8	0	5.5	1.4
TOTALS	100.0	100.0	100.0	100.0

CHAPTER IV. MAJOR WATER RIGHT APPLICATIONS IN THE TUOLUMNE RIVER BASIN

This chapter begins with some general statements on the California law of water rights.

The chapter then discusses water rights pertaining to the existing water developments of the City and County of San Francisco, and the Turlock, Modesto, and Waterford Irrigation Districts in the Tuolumne River Basin.

Next, apparent water rights of agencies interested in developing the waters of the Tuolumne River in the future are discussed. The State of California, Tuolumne County, Tuolumne County Water District No. 2, and the Modesto and Turlock Irrigation Districts have filed applications to appropriate water for use resulting from further development of the waters of the Tuolumne River Basin.

Finally, the chapter discusses the effect of water rights on projects described in this bulletin.

California Water Rights

All rights to water in California are usufructuary. They consist only in rights to the beneficial use of the water. Water itself is subject to ownership only when it has been taken into actual possession. One who has a usufructuary right is entitled to have the water in the surface streamflow to the point of his diversion, or to his riparian lands, without the unlawful interference by upstream diverters who have rights which are inferior to his.

Riparian and appropriative rights to surface water are recognized in California. Riparian rights are paramount until lost or impaired by grant, condemnation, or prescription. Correlative rights to ground water, also recognized in California, are analogous to riparian rights to surface waters.

All water rights, both surface and underground, are subject to the doctrine of reasonable use expressed in Section 3 of Article 14 of the State Constitution. This doctrine limits such rights to the quantity of water reasonably required for beneficial use and prohibits waste. unreasonable use, or unreasonable methods of diversion or use.

Riparian Rights

Riparian rights are part and parcel of riparian lands; i.e., lands contiguous to a natural watercourse within a watershed. They extend only to the smallest tract, so situated, held within the continuous chain of ownership. Each riparian right is correlative with each and every other such right within the watershed. In the event of insufficient water for all, the available supply must be prorated, except that an upper riparian owner may take the whole supply if necessary for domestic use. Riparian rights extend to future reasonable requirements for beneficial use upon riparian lands.

Riparian rights do not extend to use of water on non-riparian lands, nor do they permit the seasonal storage of water. They are not created by use nor are they lost by nonuse. They do not prevent temporary appropriation by others of water not presently needed on riparian lands. The rights may be severed or lost, in whole or in part, by grant or condemnation, and they cannot thereafter be restored. A parcel of land loses its riparian right when separated from contact with a stream by conveyance, unless the right is specifically reserved by the grantor. Riparian rights cannot be transferred for use upon another parcel of land.

Riparian rights are superior to appropriative rights, except in the case of rights founded upon appropriations of water upon vacant public lands initiated before valid steps were taken to remove the riparian lands from the domain of the United States, regardless of whether the appropriative diversions and/or the lands they serve are upstream or downstream from the riparian lands.

Appropriative Rights

The miners of the early gold-seeking period established a system of appropriative water rights in California. Their procedure was based simply on beneficial use and required no recordation in establishing the right. The first procedure requiring recordation in perfecting an appropriative right was the Civil Code enactment of 1872 (Civil Code Section 1410-1422). This procedure, modified several times, was in use until the Water Commission Act (Calif. Stats. 1413, Ch. 586) became effective on December 19, 1914.

The oldest of the procedures to perfect an appropriative right required simply that a diversion be made and the water be put to beneficial use. Beneficial use established the date of priority of the right.

The appropriation procedure provided in the 1872 Civil Code required an appropriator to post a notice in writing in a conspicuous place at the point where he intended to divert water. The notice was required to state the number of inches of water claimed by the appropriator, measured under a four-inch pressure. The purpose of the appropriation, the means of diversion, and the

place of intended use were also required to be included in the notice. A copy of the notice was required to be recorded in the office of the county recorder within ten days after being posted. The appropriative right thus initiated became perfected when the water was diligently put to beneficial use, but the right related back to the time the notice was posted. While the 1872 Civil Code procedure was the first to require recordation, it was not an exclusive procedure in that an appropriative right still could be perfected to the extent of beneficial use simply by diverting the water and making beneficial use of it.

The Water Commission Act, on the other hand, established an exclusive procedure for the appropriation of water. This enactment requires that a permit be obtained from the State of California before water can be appropriated. The procedure outlined by the Water Commission Act, as now codified in Division 2 of the Water Code, requires that an application to appropriate water be submitted to the State Water Rights Board. Upon approval of the application, a permit is issued so that the applicant can construct the features necessary to put the water to beneficial use. When the project has been completed, an inspection is made; and a license is issued, to the extent of beneficial use, provided the terms and conditions of the permit have been fulfilled.

In general, water may not be appropriated for a distant future use. Once an appropriative water right has been initiated, it must be diligently prosecuted to completion in order to maintain its date of priority. An exception is allowed in the case of an

appropriation for a municipality as will be discussed later in the chapter.

The right to appropriate once gained may be lost by abandonment, and, unless excepted by statute as in the case referred to above, by continuous nonuse. In the case of an appropriation initiated prior to 1914, the period of continuous nonuse is five years, while under the Water Commission Act, or the Water Code (Water Code Section 1241), the period of continuous nonuse is only three years.

Ground Water Rights

The permit and license procedure established by the Water Commission Act applies only to streams and other bodies of surface water and to subterranean streams flowing through known and definite channels. Percolating ground water is therefore excluded and rights to its use are governed by judicial decisions rather than by statute. Ground waters are presumed to be percolating in the absence of evidence to the contrary.

The owner of land overlying a ground water basin or stratum has, like the riparian owner, a paramount right to the reasonable beneficial use of the natural supply upon his overlying land, which right he holds in common with all other landowners similarly situated. Only surplus water in excess of reasonable requirements for beneficial use upon overlying lands is subject to appropriation for beneficial use upon other lands.

Where ground water and surface water are interconnected, one acting as a tributary to the other, both are treated as part of

a common supply, and users of water from either source are entitled to protection from substantial injury as a result of use by others of water from the other source. Thus, an owner of land riparian to a stream may have his right to the use of water protected against impairment by an appropriator of percolating ground water which is tributary to the stream and required for the maintenance and support of its flow. Likewise, where water from a stream percolates to a ground water basin or stratum, the owner of land overlying such ground water may be protected from an appropriation of water of the stream, if such use causes a substantial impairment of the ground water supply.

State Assistance

Under certain provisions of the Water Code, actions involving determinations of rights to the use of water brought in either state or federal courts may, at the court's discretion, be referred to the State Water Rights Board. Water Code Section 2000 provides that the court may appoint the board to referee "any or all issues involved in the suit," or under Section 2001 the court may limit the reference to "investigation of and report upon any or all of the physical facts involved." This reference procedure may be followed in suits involving either or both surface and ground waters.

A simplified procedure is available for preliminary determination of rights to the use of water of streams, lakes, and other bodies of water, but the method excludes the determination of rights to take water from an underground supply other than from a subter-

ranean stream flowing through known and definite channels. Water Code Sections 2500 to 2900 inclusive, authorize the initiation of such a proceeding before the board. The board then makes an engineering investigation and report, holds hearings, and prepares an order of determination which is submitted to the court. After hearings, the court makes a final determination of the water rights.

Court actions which involve a determination of relative rights to the use of water of a stream or stream system or ground water basin afford a basis for distribution of water after decree under watermaster service. Water users may secure the services of the Department of Water Resources under Water Code Sections 4000 to 4407 inclusive, in making distribution of the water to them according to their respective rights, as determined by the court.

State Applications

The State, as well as an individual, may file an application to appropriate water. It does so under Section 10500 of the Water Code. This section authorizes the Department of Water Resources to file applications for any unappropriated water which in the judgment of the department may be required for the development or completion of a general or coordinated plan for the use, conservation, or development of such waters in the State. The effect of the filing of the applications is to hold such water in public trust for future use.

County of Origin Law. The County of Origin Law--Section 10505 of the Water Code--forbids either release from priority or

assignment of state applications to appropriate water when, in the judgment of the California Water Commission, either act would deprive a county of any water originating in that county which is necessary to that county's development. The protection provided by this law has three principal limitations:

- It applies only to water originating within a county.
- It applies only to water covered by state applications to appropriate water.
- It requires the Legislature periodically to relieve the State from requirements of diligence which would invalidate such applications unless they were diligently pursued through the stages of permit and license.

Water Rights Pertaining to Existing Water Developments in the Tuolumne River Basin

Many applications to appropriate waters of the Tuolumne River Basin have been filed since the effective date of the Water Commission Act. Water rights claims initiated prior to the Water Commission Act have not been comprehensively authenticated by court decree and are generally supported only by the claims of the appropriators.

The major users of the waters of the Tuolumne River Basin are:

- City and County of San Francisco
- Turlock Irrigation District
- Modesto Irrigation District
- Waterford Irrigation District

The Pacific Gas and Electric Company operates the Phoenix System which imports water from the South Fork Stanislaus River to

Sullivian Creek, a tributary of Tuolumne River. Applications by individuals and local agencies to appropriate relatively small amounts of water from Tuolumne River, and existing rights to water from the Tuolumne River below La Grange Dam, are not discussed in this bulletin.

The City and County of San Francisco

The City and County of San Francisco claim the right to divert up to 450,000 acre-feet annually from the Tuolumne River System. Water rights are claimed in connection with the three principal reservoirs of their Hetch Hetchy System. These reservoirs are:

- Lake Eleanor (Capacity 27,100 acre-feet) on Eleanor Creek
- Lake Lloyd (Capacity 268,000 acre-feet) on Cherry Creek
- Hetch Hetchy (Capacity 360,000 acre-feet) on Tuolumne River

Diversions from Lake Eleanor and Lake Lloyd Reservoirs pass through Cherry Tunnel to the Cherry Powerhouse (installed capacity: 135,000 kilowatts), discharge into Cherry Creek below its confluence with Eleanor Creek, and continue down Cherry Creek to the Tuolumne River. The City and County of San Francisco operate Lake Eleanor and Lake Lloyd Reservoirs, not only to produce power but also to control floods and to supply water to the Turlock, Modesto, and Waterford Irrigation Districts. These downstream irrigation districts possess prior appropriative rights to Tuolumne River water. If not met by natural streamflow plus releases from Lake Eleanor and Lake Lloyd Reservoirs, these appropriative rights would have to be met by releases into the Tuolumne River from Hetch Hetchy Reservoir. Waters

which are to be diverted from the Tuolumne River Basin to the San Francisco area are released from Hetch Hetchy Reservoir and flow in the Tuolumne River to Early Intake (a low diversion structure on the Tuolumne River 1.5 miles above its confluence with Cherry Creek) where the water is diverted into the Hetch Hetchy Aqueduct. This aqueduct conveys waters of the Tuolumne River through more than 150 miles of tunnel and pipeline to San Francisco and the south bay area.

Water rights of the City and County of San Francisco in the Tuolumne River Basin have not been completely clarified by court decree. The City and County of San Francisco made a public statement in March 1955. Appearing before a subcommittee on irrigation and reclamation of the committee on Interior and Insular Affairs, House of Representatives, Mr. R B. Hansen, senior engineer in charge of water rights. rights-of-way, and lands of the Hetch Hetchy System, presented the statement which is contained in a document entitled "Hearings before the Subcommittee on Irrigation and Reclamation of the Committee on Interior and Insular Affairs, House of Representatives, Eighty-fourth Congress, First Session, on H. R. 2388, to Authorize the Construction, Operation, and Maintenance of a Hydroelectric Project on the Tuolumne River. California," pages 128-129, as the Early Intake Power Project No. 2. A portion of the statement reads as follows:

> "The water appropriations of the City and County of San Francisco antedate all valid appropriations on the Tuolumne River and its tributaries, except the 2,350 second-feet for which the Modesto and Turlock Irrigation Districts had diverting capacity at the time the city's appropriations were made and one additional appropriation of 66 second-feet made by the La Grange Ditch Company on October 19, 1872. This right was subsequently sold to the Waterford

Irrigation District. . . . This water right for 66 second-feet may be considered as having priority over all other water rights on the Tuolumne River, since it is the first water right filed on said river.

". . . the Raker Act, . . which also recognized the right of the districts to take 4,000 second-feet of water from the Tuolumne River during the 60 days immediately following and including April 15 of each year, provided the districts were capable of beneficially using and storing said water.

"The Hetch Hetchy water supply project is based on the right, with the aid of adequate storage, to ultimately divert to the San Francisco Bay area 400 million gallons of water daily from the Tuolumne River, Eleanor Creek, and Cherry River, the latter two sources being tributaries of the former. . . . The right of the city to divert water from the Tuolumne River . . . is based on . . . three appropriations . . . . These appropriations total 60,000 miners inches, which is equivalent to 1,200 cubic-feet of water per second."

Recent water exports through the Hetch Hetchy System averaged about 167,000 acre-feet annually, with a maximum of 174,000 acre-feet.

Water Code Sections 106.5 and 1203 declare the policy of the State with reference to the interim use of water which a municipality may have a right to appropriate but for which the municipality has no present reasonable need. These sections read as follows:

"106.5. It is hereby declared to be the established policy of this State that the right of a municipality to acquire and hold rights to the use of water should be protected to the fullest extent necessary for existing and future uses, but that no municipality shall acquire or hold any right to waste water, or to use water for other than municipal purposes, or to prevent the appropriation and application of water in excess of its reasonable and existing needs to useful purposes by others subject to the rights of the municipality to apply such water to municipal uses as and when necessity therefor exists.

"(Added by Stats. 1945, ch. 1344)

Note--Stats. 1945, ch. 1344, also contained the following:

"Sec. 3. The purpose of this act is to effectuate the policy declared in Section 2 of this act and this act shall be liberally construed by the judicial and executive branches of the State Government to carry out its purpose.

"1203. Any water the right to the use of which is held by any municipality which is in excess of the existing municipal needs therefor may be appropriated by any person entitled to the possession of land upon which such excess water may be put to beneficial use but the right of such person to use such water shall continue only for such period as the water is not needed by the municipality. This section supplements but does not otherwise affect Sections 1460 to 1464, inclusive.

"(Added by Stats. 1945, ch. 1344. See note to Section 106.5.)"

The City of San Francisco is presently using less water than it claims rights to. It would seem, therefore, that there is water which can be used in the Tuolumne River Basin until such time as the City and County of San Francisco have use for the full amount of their claimed water rights.

Turlock, Modesto, and Waterford Irrigation Districts

The Turlock and Modesto Irrigation Districts completed construction of Don Pedro Reservoir in 1923. This reservoir, on the Tuolumne River near La Grange, has a storage capacity of 289,000 acre-feet.* Water released from the reservoir through Don Pedro Powerplant flows down the Tuolumne River into La Grange Reservoir. Releases are made from La Grange Reservoir to canals supplying the Turlock, Modesto, and Waterford** Irrigation Districts.

* The Turlock and Modesto Irrigation Districts and the City and County of San Francisco are presently planning an enlargement of this reservoir to 2,030,000 acre-feet.

** Waterford Irrigation District's entitlements are diverted at La Grange Dam by Modesto Irrigation District and transported via their main canal to Waterford Irrigation District's main canal near Roberts Ferry.

Diversions of the Turlock, Modesto, and Waterford Irrigation Districts from the Tuolumne River for the period 1914 through 1958, as reported to the State Water Rights Board, ranged from a minimum of 730,000 acre-feet in 1947 to a maximum of 950,000 acre-feet in 1956 and averaged 875,000 acre-feet annually. Published records of the United States Geological Survey show diversions to the districts for the same period as averaging about 6 percent higher than the quantities reported by the districts. The higher values probably result from the inclusion of minor winter diversions that subsequently return to the Tuolumne River.

Table 18, entitled "Summary of Major Water Right Applications Filed with the State Water Rights Board by Turlock and Modesto Irrigation Districts for Existing Projects," lists the water rights in the Tuolumne River Basin which apply to the operation of existing projects of the Turlock and Modesto Irrigation Districts and which have been acquired since December 19, 1914, the effective date of the Water Commission Act. The claimed water rights of Turlock, Modesto and Waterford Irrigation Districts established prior to December 1914 are shown in Appendix D.

Major Water Rights Applications for Projects Not Yet in Operation

Applications to appropriate water have been filed by several agencies interested in further developing the Tuolumne River. These agencies are:

- State of California
- Tuolumne County
- Tuolumne County Water District No. 2
- Turlock and Modesto Irrigation Districts

TABLE 18

SUMMARY OF MAJOR WATER RIGHT APPLICATIONS FILED
WITH THE STATE WATER RIGHTS BOARD
BY TURLOCK AND MODESTO IRRIGATION DISTRICTS FOR EXISTING PROJECTS

Application number	Applicant and status	Source and facility	Diversion second feet	Storage acre-feet annually	Major use
		Tuolumne River			
1232	License 5420	Don Pedro Reservoir		325,000	Power
1233	License 5417	Don Pedro Reservoir		325,000	Irrigation
1532	License 5421	Don Pedro Dam	2,558		Power
3139*	License 2580	La Grange Dam	603		Power
3648	License 2424	La Grange Dam	100		Irrigation
6711	License 2425	La Grange Dam	800		Irrigation
9996	License 5418	Don Pedro Dam La Grange Dam	1,200		Power
9997	License 5419	La Grange Dam	1,200		Irrigation
		Cherry Creek			
13563	Permit 9317	Lake Lloyd Reservoir**	290	153,000	Irrigation
13604	Permit 9318	Lake Lloyd Reservoir**	290	153,000	Power
		Eleanor Creek			
13563	Permit 9317	Lake Lloyd Reservoir**	210	111,000	Irrigation
13604	Permit 9318	Lake Lloyd Reservoir**	210	111,000	Power

*Filed by Turlock Irrigation District only.
**Lake Lloyd Reservoir is named Cherry Valley Reservoir in applications.

The Turlock and Modesto Irrigation Districts have filed applications to appropriate water necessary for the operation of the proposed enlarged Don Pedro Reservoir. Tuolumne County Water District No. 2 filed applications to appropriate water required to develop the Tuolumne Project described in Bulletin No. 95, entitled "Tuolumne County Water District No. 2 Investigation." Tuolumne County has filed applications to appropriate the water required to develop the Middle Fork Tuolumne River and South Fork Tuolumne River. The State of California filed application No. 5649 which includes water rights on Sullivan Creek necessary for operation of the Tuolumne Project described in Bulletin No. 95. Subsequent to these filings the County of Tuolumne and Tuolumne County Water District No. 2 entered into an agreement with the City and County of San Francisco and the Turlock, Modesto, and Waterford Irrigation Districts, whereby certain applications to appropriate water would be withdrawn. This agreement is included in this report as Appendix C.

Table 19, entitled "Summary of Major Water Rights Applications Filed with the State Water Rights Board For Projects Not Yet in Operation in Tuolumne River Basin," summarizes the applications filed by the above interested agencies.

Effect of Water Rights on Projects Described in this Bulletin

Water rights held by Turlock, Modesto, and Waterford Irrigation Districts, together with the claims to water rights by the City and County of San Francisco, are equal to the 50-year mean annual natural runoff of Tuolumne River at La Grange. Thus, any project on the upper Tuolumne River which results in consumptive use of water would deplete the total water supply of the river, and would affect existing water

TABLE 19

SUMMARY OF MAJOR WATER RIGHTS APPLICATIONS
FILED WITH THE STATE WATER RIGHTS BOARD
FOR PROJECTS NOT YET IN OPERATION IN TUOLUMNE RIVER BASIN

Application number	Applicant and status	Source and facility	Diversion second-feet	Storage acre-feet annually	Major use
	STATE OF CALIFORNIA (Unassigned applications)				
		Sullivan Creek			
5649	Incomplete	Enlarged Phoenix	50	13,000	Irrigation
	TUOLUMNE COUNTY				
		North Fork Tuolumne River			
12871	Pending	Pumping Station below Browns Meadow Reservoir	1		Municipal
		Middle Fork Tuolumne River			
13011	Pending	SW-1/4 Section 12, T1S, R19E, MDB&M	200		Power
		South Fork Tuolumne River			
12871	Pending	Harden Reservoir	1	1,000	Municipal
13011	Pending	Harden Reservoir		24,000	Power
13011	Pending	Crocker Reservoir	100	53,000	Power
13012	Pending	Harden Reservoir	125	24,000	Irrigation
13012	Pending	Crocker Reservoir		53,000	Irrigation
	TUOLUMNE COUNTY WATER DISTRICT NO. 2				
		Lily Creek			
19423	Pending	Pine Valley Reservoir	200	3,800	Irrigation
19424	Pending	Pine Valley Reservoir	200	3,800	Power
		Bell Creek			
19423	Pending	Bell Meadows Reservoir	200	12,300	Industrial
19424	Pending	Bell Meadows Reservoir	200	12,300	Power
		North Fork Tuolumne River			
12493	Pending	Browns Meadow Reservoir		9,250	Irrigation
12493	Pending	Lewis Reservoir		3,500	Irrigation
12497	Pending	Browns Meadow Reservoir	25	9,250	Power
12498	Pending 1/	Browns Meadow Reservoir	3	6,000	Municipal
12498	Pending 1/	Lewis Reservoir		2,000	Municipal
19423	Pending	Browns Meadow, Lyons, and Phoenix Reservoirs	200	13,600	Industrial
19424	Pending	Browns Meadow, Lyons, and Phoenix Reservoirs	200	94,600 2/	Power

1/ Being amended by agreement.

2/ Includes offstream storage of 9,600 acre-feet in Phoenix Reservoir and 81,000 acre-feet in Browns Meadow Reservoir.

TABLE 19 (Continued)

SUMMARY OF MAJOR WATER RIGHTS APPLICATIONS
FILED WITH THE STATE WATER RIGHTS BOARD
FOR PROJECTS NOT YET IN OPERATION IN TUOLUMNE RIVER BASIN

Application number	Applicant and status	Source and facility	Diversion second-feet	Storage acre-feet annually	Major use
	TUOLUMNE COUNTY WATER DISTRICT NO. 2 (continued)				
		Sullivan Creek			
12257	Pending 1/	Phoenix Reservoir		10,750	Irrigation
12257	Pending 1/	Sullivan Creek Reservoir		1,000	Irrigation
12856	Pending 2/	Belview Reservoir	40	1,450	Irrigation
13875	Pending 2/	Stent Reservoir		41,700	Irrigation
		Curtis Creek			
12856	Pending 2/	Standard and Dunning Reservoirs	20	13,000	Irrigation
		Sixbit Gulch			
12856	Pending 2/	Sixbit Gulch Reservoir	20	16,000	Irrigation
		Woods Creek			
12856	Pending 2/	NE-1/4, SE-1/4, Section 16, T1N, R14E	20		Irrigation
13827	Pending 2/	SW-1/4, SW-1/4, Section 1, T1N, R14E	25		Irrigation
15968	Permit 12578	NW-1/4, NE-1/4, Section 11, T1N, R14E	1		Irrigation
	TURLOCK AND MODESTO IRRIGATION DISTRICTS				
		Tuolumne River			
14126	Permit 9319	New Don Pedro Reservoir		1,568,300	Power
14127	Permit 9320	New Don Pedro Reservoir		1,568,300	Irrigation

1/ Being amended by agreement.
2/ Withdrawn subsequent to filing, by agreement.

rights on the river. Inasmuch as the water rights of the irrigation districts are prior in time to those of the City and County of San Francisco, any such project would have an effect upon the latter. For example, if a project should deplete the water supply at Don Pedro Reservoir, the Turlock and Modesto Irrigation Districts could require the City and County of San Francisco to release water from their Hetch Hetchy Project to replace the depletion. Thus, although the project might not divert any water tributary to the Hetch Hetchy System, it would still have an adverse effect on the Hetch Hetchy System.

To enable the full economic development of the Upper Tuolumne River watershed, Tuolumne County Water District No. 2 and the County of Tuolumne (referred to as "Tuolumne County Interests") have negotiated an agreement with Turlock Irrigation District, Modesto Irrigation District, Waterford Irrigation District, and the City and County of San Francisco (referred to as "Downstream Interests"). As previously stated a copy of the agreement is included as Appendix C. Under the terms of this agreement, the Downstream Interests will not protect certain applications to appropriate water for domestic and municipal uses, and such nonconsumptive uses as recreation, fish and wildlife enhancement within the boundaries of Tuolumne County, provided the Tuolumne County Interests will withdraw certain applications to appropriate water and will operate projects developed under the unprotested applications to appropriate water according to the criteria set forth in the agreement. Execution of this agreement should facilitate further study and possible construction of projects such as, or similar to, those outlined in this bulletin and those in Bulletin No. 95, entitled "Tuolumne County Water District No. 2 Investigation."

CHAPTER V. PLANS FOR WATER DEVELOPMENT

Southern Tuolumne County has developable hydroelectric power, water associated recreation, and local water supply potentials. There is a need in the State for more power and for additional availability of outdoor recreation. Preceding chapters show that local water supplies are needed. It is the policy of the Department of Water Resources to further the optimum utilization of the water resources of this State.

Many projects to develop the several water associated resources and to supply water were studied on a reconnaissance basis. Four basic types of projects were considered: (1) enlargement of ground water use, (2) diversion from the Hetch Hetchy Aqueduct, (3) construction of small reservoirs on streams in the Groveland area, and (4) construction of major conservation works on the Middle and South Forks of the Tuolumne River. The reconnaissance studies indicate that the major conservation works would most economically develop the resources of the area. Subsequently, the two most likely major conservation projects were selected for further study. These two projects were named "The Harden Project" and "The Groveland Project."

This chapter contains (1) a discussion of the principles used in formulating and evaluating the projects, (2) a discussion of the possible alternative solutions to the water supply problems of Southern Tuolumne County, (3) a detailed description of the features and accomplishments of the Harden Project, and (4) a comparison of the features and accomplishments of the Groveland Project with those of the Harden Project.

Planning Considerations

Formulation and evaluation of the projects considered for the development of waters in the Tuolumne River Basin required studies of reservoir operation, geology, designs, cost estimates, benefits, and economic justification. Determination of financial feasibility of the project which may be proposed would require further detailed studies and design (see page A-7 in Appendix A, "Agreement").

Operation Studies

Reservoir operation studies to determine the water yield that would be available for both nonconsumptive and consumptive uses were made for the 35-year base period (October 1, 1920, through September 30, 1955).

The principal assumptions used in conducting the studies are as follows:

- The controlling power capacity factor would be 30 percent in the year 2020.*
- Provision would be made for minimum reservoir pools that would protect fish life.
- Streamflow releases would be sufficient to maintain a fishery and, where possible, would enhance the existing conditions.
- Water would be made available to satisfy consumptive needs of the Groveland Unit where economically justified.
- Since flood damages in the area in the past have been relatively light, the proposed projects would provide flood control only from incidental operation of the reservoirs.

Geologic Studies

Based on geologic problems encountered and size of proposed structures, the program of geologic exploration for this investigation varied from reconnaissance studies of surficial geologic features at some sites to subsurface exploration at other sites. This program included:

* A 30 percent capacity factor assumes a water supply sufficient to operate the powerplant at rated generating capacity for 30 percent of the year, on a power demand schedule.

- Surface geologic mapping of dam and reservoir sites and conduit routes.
- Preliminary foundation drilling of the Groveland damsite.
- Collection of soil samples to determine the suitability of proposed borrow pits as sources of construction materials.
- Determination of the amount of material available for construction.

The files of the Department of Water Resources contain results of these studies.

Designs and Cost Estimates

Engineering designs and estimates of cost were made for several sizes and types of dams for each of the sites considered. Project features were designed in accordance with standard engineering principles to obtain the most economical combination of dam, spillway, and outlet works and to determine the optimum project considering benefits to be realized.

Although the project features discussed are believed to represent those which would be constructed to accomplish the purposes of the project, further exploration of the sites and more thorough analyses might develop information that would necessitate changes in design. In turn, such changes might bring about changes in costs and/or sizes.

Capital costs of each project, based on prices prevailing in 1961, include estimated costs of construction, land acquisition, and utility relocation. The costs also allow for engineering, administration, construction contingencies, and interest during construction.

Annual costs include those of replacement, operation, maintenance, general expense, and amortization of the capital investment during a 50-year repayment period with an interest rate of 4 percent.

Property descriptions and information on land ownership supplied by the Tuolumne County Assessor were used in estimating the value of lands, utilities, buildings, and other structures at the sites of reservoirs described in this bulletin.

Each tract of land was appraised by a market analysis method which compared the land with similar property that had been involved in recent sales. The county recorder and local real estate agencies supplied data on such sales and on the costs of properties in or near the area involved.

The value of buildings, structures, and roads was assumed to be their estimated cost of replacement, under present conditions, with similar buildings, structures, and roads of comparable utility. The roads involved are unimproved United States Forest Service roads and improved county roads.

The market value of lands which would be inundated by reservoir development was considered equal to the present worth of their future productivity.

Benefit Estimates

Projections of population growth, land and water use, and recreation use were made as initial steps in estimating benefits -- the net gains directly realized from the projects.

Irrigation Benefits. Computations were made of the benefits to be derived from the inclusion of irrigation as a project purpose to provide water to previously dry-farmed or intermittently irrigated land.

The irrigation benefit (returns to land and water) is computed by subtracting from the gross farm income all farm production costs except the costs of land and water. The project irrigation benefit then is defined as those returns to land and water under project conditions which are in excess of the returns to land and water under nonproject conditions.

The irrigation benefits to the unit were determined as the product of the acreages devoted to deciduous orchard and improved pasture, and the irrigation benefit per acre resulting from each crop. These estimated irrigation benefits were $56 per acre for deciduous orchard and $35 per acre for improved pasture. The weighted average unit irrigation benefit in the Groveland Unit over the years of project repayment would be about $38 per acre.

Domestic Benefits. In evaluating benefits that would accrue from domestic use of water, the concept of vendibility, limited by the next least costly alternative source, was used. In 1961, Pacific Gas and Electric Company provided treated water to 2,126 customers in the communities of Sonora, Jamestown, and Tuolumne. A total of 1,113 acre-feet of water was sold for $127,395 at an average of $114.40 per acre-foot. The present worth of the least costly alternative of supplying the total domestic water

requirements of the Groveland-Big Oak Flat area by pumping from the Hetch Hetchy Aqueduct would be approximately $700,000. To repay this $700,000 a charge of $67.50 per acre-foot would be required. It is estimated that the demand for domestic water would increase from about 200 acre-feet in 1970 to about 1800 acre-feet by 2020. It was therefore concluded that the domestic water benefits were those of the least costly alternative (i.e., $700,000).

Recreation Benefits. Recreation benefits were determined as the mathematical product of the dollar value of a visitor-day* or angler-day of use and the number of visitor- or angler-days attributable to the project. The dollar value of each visitor- or angler-day in areas of water-associated recreation made possible by projects in the Southern Tuolumne area was estimated to be $2.20.

To estimate the number of visitor- or angler-days of use, the department considered the effect of increasing population, increasing leisure time, increasing mobility, and increasing disposable income on present and future demands for recreation. Such factors as present use of the area, the room available for additional facilities, and the increased attractiveness of the area were considered with the recreation demand to estimate how much of this demand would be satisfied in the project area during each decade of the 50-year project repayment period. It was

* A visitor-day is the unit of measurement of the use of a public recreation area. One visitor-day represents use by one visitor for any portion of a day. An angler-day is a similar unit of measurement as it pertains to use of such an area by a fisherman.

estimated that the Harden Project would cause an additional average of 524,000 visitor-days of recreational activity per year over the 50-year repayment period and thereby create benefits which would have a present worth of approximately $19,840,000.

Power Benefits. The cost of power from the alternative source most likely to be used in the absence of the project normally provides a measure of the power benefits. In the case of projects presented in this report, such an alternative source would be a privately financed steam-electric plant. Based on this cost, the following estimated values of hydroelectric power were used in this bulletin: dependable capacity* component, $24.50 per dependable kilowatt per year; and energy component, 3.1 mills per kilowatt-hour. Studies of future power requirements in Northern and Central California resulting from predicted population growth and increased annual per capita use of electricity indicated that there would be a ready market for project power.

Economic Justification Studies

The comparison of the present worth of project benefits and the present worth of project costs commonly is expressed in the form of a ratio called the benefit-cost ratio. A project may be considered to be economically justified if its benefits exceed its costs of design, construction, operation, maintenance, and replacement -- in other words, if its benefit-cost ratio exceeds

* Dependable capacity is the ability of a generating plant to maintain a particular load for the time interval and period specified.

unity. Further, there must be no less costly alternative means of accomplishing the purposes of the project.

The projects presented in this chapter were developed so as to provide maximum excess of benefits over costs.

Water Conservation Possibilities

The several possible methods of developing the water resources and meeting the water needs in Southern Tuolumne County considered during the investigation included:

- Increased development of ground water
- Diversion from Hetch Hetchy Aqueduct
- Direct diversion of unregulated streams
- Further regulation of surface water

A discussion of each of these methods follows.

Increased Development of Ground Water

As was explained in Chapter II, Water Supply, the only water-bearing rocks having any possibility of development for other than individual or small group use are the tertiary gravels located near Burch Meadows. Insufficient data are available on the volumne of storage available and on the natural recharge characteristics of this ground water basin to enable a reasonable estimate of the possible yield. Preliminary comparisons of costs of alternative water sources indicate that a cost of a water supply from the Harden Project as proposed in this bulletin would be less than the $751,000 required for development of ground water. Further, the ground water source would be less dependable and probably of poorer quality. Therefore, the Harden Project was considered

preferable to the development of the tertiary gravel ground water basin. Further study should be made of ground water if a single purpose water supply project were to be found desirable.

Diversion from the Hetch Hetchy Aqueduct

Diversion of water from the access shaft of the Hetch Hetchy Aqueduct in Second Garotte Basin was considered as a single purpose domestic water supply for the Groveland-Big Oak Flat area. Reconnaissance cost estimates indicate that it would cost approximately $700,000 to provide a water supply equivalent to that which would be supplied by the Harden Project. The separable cost of water supply in the Harden Project is approximately $390,000 and the allocated costs of water supply is $610,000. It would seem that obtaining a water supply from the Harden Project is the better method. However, the use of the Hetch Hetchy water supply as a first stage or interim supply might prove with further study to be economically justified and financially feasible.

Direct Diversion of Unregulated Streams

Direct diversion from small streams within Southern Tuolumne County is severely limited as a method of obtaining additional water supplies because of the scanty and intermittent flow of these streams during the irrigation season.

Direct diversion from major streams is handicapped by the fact that these streams are deeply intrenched. Such diversion would require either long conduits or high pumping heads.

Furthermore, the entire flow of these streams during months of low runoff is used or reserved for future use under present water rights or claims to water rights. Although residents of Southern Tuolumne County use some water from these streams, the greatest use is by residents of the irrigation districts on the valley floor of the San Joaquin Valley and by residents of the San Francisco Bay area served by the Hetch Hetchy System.

In consideration of the foregoing, direct diversion from streams without provision for water storage is not a practical way to develop new water supplies.

Further Regulation of Surface Water

In light of the preceding conclusions, construction of storage reservoirs was deemed the only other practical way to provide substantial quantities of new water for use within Southern Tuolumne County.

The use of small streams in Southern Tuolumne County as a source for a water supply would result in a series of small, widely separated reservoirs. The dispersal of these reservoirs would result in increased distribution and operation costs. Also, these reservoirs would be small and would present problems associated with warm and possibly algae-infested water. Small intermittent flows associated with lesser streams provide low firm yields for any given investment. Minor reservoirs might provide some interim development.

The use of the main stem of Tuolumne River or the Clavey River as a source of water supply would require expensive facilities

to lift the water from the deeply intrenched rivers to the areas of use. The most reasonable source for supplying water to the Southern Tuolumne area would be the South Fork Tuolumne River, the Middle Fork Tuolumne River, and Big Creek. An inventory of potential reservoirs on these streams was therefore conducted.

Bulletin No. 3, "The California Water Plan," and Bulletin No. 56, "Survey of Mountainous Areas," suggest several reservoir sites in connection with potential projects for developing the waters of the Tuolumne River. All such projects were considered in development of plans during this investigation. The most favorable sites for new reservoirs are as follows:

- Harden Flat Reservoir on South Fork Tuolumne River
- Burch Meadow Reservoir on Big Creek
- Groveland (Big Creek) Reservoir on Big Creek

Carl Inn Reservoir, which would be formed by a dam on the South Fork Tuolumne River about 0.5 mile west of the boundary of Yosemite National Park, was considered as a possible solution to the area's water problems. This reservoir was rejected, however, because the available reservoir capacity is limited by topographic and right-of-way considerations.

Harden Project

The Harden Project would consist of the following features:

- Mather Diversion
- Mather Ditch
- Harden Flat Reservoir
- Golden Rock Ditch
- Lost Claim Forebay
- Lost Claim Powerplant

- Burch Meadow Conduit
- Burch Meadow Reservoir

Plate 6, entitled "Plan and Profile of Harden Project," shows the relationships of the proposed features. Table 20, entitled "Physical Characteristics of Proposed Features of the Harden Project," gives information relating to these features. Table 21, entitled "Water Depths, Areas, and Capacities of Proposed Reservoirs of the Harden Project," lists areas and capacities of the potential reservoirs at various water depths.

Chapter III shows that there exists a need for additional water within Southern Tuolumne County. The Harden Project on the Middle Fork and South Fork of the Tuolumne River and on Big Creek would provide additional water for domestic uses. The project would supply about 1,800 acre-feet of domestic water for use in the service area of the Harden Project. This amount of water will meet the estimated year 2020 requirements for domestic water in that area. The project also would produce substantial amounts of hydroelectric power at Lost Claim Powerhouse. This powerplant would have an installed capacity* of 22,000 kilowatts and would produce about 90,700,000 kilowatt-hours of energy annually, including off peak energy.

In addition to providing water for domestic purposes and for power production, the waters of project reservoirs would provide new opportunities for recreation by opening areas suitable

* Installed capacity is the sum of the name plate rating of the generators in the powerplant.

TABLE 20

PHYSICAL CHARACTERISTICS OF PROPOSED FEATURES OF THE HARDEN PROJECT

Feature	Mather Diversion	Harden Flat	Lost Claim Forebay	Burch Meadow
Dam				
Type	Concrete O.G. weir	Earth and rockfill	Earth and rockfill	Modified homogeneous earthfill
Elevation of streambed, in feet	4,640	3,435	--	2,976
Crest elevation, in feet	4,675	3,670	--	3,052
Crest height above streambed, in feet	35	235	--	76
Crest length, in feet	270	750	--	700
Crest width, in feet	30	30	--	30
Slopes: Upstream face:	--	2:1	--	4:1
Impervious core	--	0.75:1	--	--
Downstream face:	--	2:1	--	2.5:1
Impervious core	--	0.75:1	--	--
Volume of fill, in cubic yards	2,400	1,640,000	--	267,000
Spillway				
Crest elevation, in feet	4,660	3,655	No Spillway	3,044
Crest height above approach channel, in feet	20	10	--	6
Crest length, in feet	200	300	--	50
Freeboard above crest, in feet	15	15	--	8
Maximum probable flood peak outflow, in second-feet	36,000	58,000	--	4,700
Reservoir				
Storage capacity at minimum pool, in acre-feet	15	1,000	50	--
Storage capacity at normal pool, in acre-feet	25	42,000	50	3,550
Surface area at minimum pool, in acres	5	76	25	--
Surface area at normal pool, in acres	10	430	25	188
Drainage area, in square miles	44	82	--	2.65

Conduit	Mather Ditch		Golden Rock Ditch			Burch Meadow Conduit	
	Canal	Flume	Canal	Flume	Siphon	Canal	Siphon
Type	Trapezoidal	Lennon	Trapezoidal	Lennon	Inverted	Trapezoidal	Inverted
Length, in miles	3.0	0.5	8.0	0.4	0.4	2.5	0.6
Capacity, in second-feet	150	150	165	165	165	10	10
Diameter, in feet	--	9.5	--	9.5	4.16	--	1.16
Lining	Gunite	--	Gunite	--	--	Gunite	--
Inlet elevation, in feet	4,640	--	3,460	--	--	3,400	--
Outlet elevation, in feet	4,600	--	3,400	--	--	3,250	--

Powerplant	Elevation, in feet		Power capacity, in kilowatts		Maximum static head, in feet
	Penstock inlet	Tailrace	Installed	Dependable	
Lost Claim	3,400	1,400	22,000	22,000	2,000

TABLE 21

WATER DEPTHS, AREAS, AND CAPACITIES OF
PROPOSED RESERVOIRS OF THE HARDEN PROJECT

Reservoir	Water depth at dam, in feet	Water surface elevation, in feet, (USGS datum)	Water surface area, in acres	Storage capacity, in acre-feet
Mather Diversion				
	0	4,640	0	0
	20	4,660	10	50
Harden Flat Reservoir				
	0	3,435	0	0
Minimum pool	49	3,484	76	1,000
	165	3,600	290	22,000
	175	3,610	320	25,000
	185	3,620	340	28,000
	195	3,630	360	32,000
	205	3,640	390	36,000
	215	3,650	410	39,000
Normal pool	220	3,655	430	42,000
	225	3,660	450	44,000
	235	3,670	470	50,000
Lost Claim Forebay				
	0	3,380	0	0
	20	3,400	25	50
Burch Meadow Reservoir				
	0	2,976	0	0
	14	2,990	2	14
	24	3,000	5	50
	34	3,010	21	180
	44	3,020	59	570
	54	3,030	120	1,460
	64	3,040	170	2,920
Normal pool	68	3,044	188	3,550
	74	3,050	212	4,820
	84	3,060	254	7,160

for fishing, boating, camping, and summer homes. Regulated releases of water from these reservoirs would provide flows for fish and wildlife.

Effect of Project on Downstream Areas

During an average* year, the Harden Project would divert 25,800 acre-feet of the average annual supply of 40,300 acre-feet of water available at the Mather Diversion Damsite on the Middle Fork Tuolumne River, via the Mather ditch. Of the remaining 14,500 acre-feet available at Mather Damsite, 300 acre-feet would be lost to evaporation, 5,300 acre-feet would be released during months of low flows for maintenance and enhancement of fish and wildlife on the Middle Fork Tuolumne River below Mather Damsite, and 8,900 acre-feet would be spilled to Middle Fork Tuolumne River at Mather. The 25,800 acre-feet diverted from Middle Fork Tuolumne River plus the average annual supply of 63,500 acre-feet available at Harden Damsite South Fork Tuolumne River, would constitute an average annual water supply of 89,300 acre-feet at Harden Flat Reservoir. In an average year 52,700 acre-feet of the average annual supply at Harden Flat Reservoir would be diverted to Lost Claim Forebay via the Golden Rock ditch, 900 acre-feet would be lost to evaporation, 9,600 acre-feet would be released during months of low flows for maintenance, and enhancement of fish and wildlife in South Fork Tuolumne River, and 26,100 acre-feet would be spilled to the South Fork Tuolumne

* Average year is average for 35-year period from October 1, 1920, through September 30, 1955.

River. Of the 52,700 acre-feet of water diverted by the Golden Rock ditch during an average year, 35,800 acre-feet would be the firm yield and 16,900 acre-feet would be the non-firm supply. Of the 52,700 acre-feet of water diverted to Lost Claim Forebay via the Golden Rock ditch, 50,900 acre-feet would be returned to the South Fork Tuolumne River at Lost Claim Powerhouse. The remaining 1,800 acre-feet would be diverted by the Burch Meadow Conduit to the Harden Project service area. Approximately 900 of the 1,800 acre-feet would ultimately be return flow to the Tuolumne River.

The net impairment of the Harden Project on the runoff of the Tuolumne River would be approximately 2,100 acre-feet. Since the fluctuations in storage in Harden Flat Reservoir are of shorter duration than those in Don Pedro Reservoir, operation of Harden Flat Reservoir would not appreciably decrease the yield of Don Pedro Reservoir. Thus, while the Harden Project would modify the flows of the Tuolumne River, the effect of the Harden Project on downstream uses would be negligible.

Tables 22, 23, and 24 show the effects of the Harden Project on areas within Southern Tuolumne County.

° Table 22, entitled "Present Water Requirement, Year 2020 Water Supply From the Harden Project, and Estimated Maximum Water Requirements in Southern Tuolumne County," indicates the present water requirement for domestic and recreation uses, the amount of water which could be supplied from the Harden Project in year 2020, and the estimated maximum water delivery requirements for domestic and recreation use. The table shows that, with full use of the water made available by the project in 2020, need for the development of additional water will occur sometime after 2020.

° Table 23, entitled "Projected Population Within the Service Area of the Harden Project, and Projected Annual Visitor-Days of Recreation Use Attributable to the Harden Project," summarizes, by decades, the projected visitor-days of use attributable to the Harden Project and the projected population in the service area of the Harden Project. The table indicates a sizable increase in population and nearly a 20-fold increase in recreation use within the service area of the Harden Project.

° Table 24, entitled "Projected Annual Volumne of Water and Amount of Hydroelectric Power Supplied by the Harden Project," presents, by decades, the projected annual volume of water and amount of hydroelectric power to be supplied by the Harden Project. The table indicates nearly a 10-fold increase in water supply requirements during the 50-year period 1970-2020.

TABLE 22

PRESENT WATER REQUIREMENT, YEAR 2020 WATER SUPPLY FROM THE HARDEN PROJECT, AND ESTIMATED MAXIMUM WATER REQUIREMENTS IN SOUTHERN TUOLUMNE COUNTY
(In acre-feet)

Unit	Present requirement for domestic and recreation use	Supply in year 2020 from Harden Project for domestic and recreation use	Estimated maximum requirements for domestic and recreation water
Harden	*	--	2,300
Groveland	150	1,450	2,100
Moccasin**	200	350	800
TOTALS	350	1,800***	5,200

*Less than 50 acre-feet.
**The only area to be served with project water from the Harden Project is the urban area around Big Oak Flat.
***The year 2020 water requirement of about 2,800 acre-feet would include requirements outside the Harden Project service area.

Major Project Features

The following discussion considers separately each of the Harden Project features.

Mather Diversion Dam. The proposed Mather Diversion Dam would be constructed on Middle Fork Tuolumne River about 1.5 miles above the Middle Fork Campground. The location of the site is in Section 12, Township 1 South, Range 19 East, MDB&M. Present access to the reservoir is by a paved road into Middle Fork Campground and then by a pack trail established by the United States Forest Service for a distance of one mile.

TABLE 23

PROJECTED POPULATION WITHIN THE SERVICE AREA OF
THE HARDEN PROJECT AND PROJECTED ANNUAL VISITOR-DAYS OF
RECREATION USE ATTRIBUTABLE TO THE HARDEN PROJECT

Item	Year					
	1970	1980	1990	2000	2010	2020
Population type (In number of permanent residents)						
Rural	200	280	390	570	850	1,260
Urban	310	370	500	700	1,040	1,630
Suburban	280	470	740	1,200	2,010	3,510
Recreation	100	140	180	240	330	440
TOTALS	890	1,260	1,810	2,710	4,230	6,840
Recreation use (In visitor-days)						
Reservoir	41,000	258,000	463,000	556,000	594,000	603,000
Summer cabin	1,500	21,600	72,000	113,000	126,000	126,000
TOTALS	42,500	259,000	535,000	669,000	720,000	729,000

TABLE 24

PROJECTED ANNUAL VOLUME OF WATER AND AMOUNT OF
HYDROELECTRIC POWER SUPPLIED BY THE HARDEN PROJECT

Item	Year					
	1970	1980	1990	2000	2010	2020
Water supply (In acre-feet)						
Domestic and recreation	200	300	400	700	1,100	1,800
Installed power (In kilowatts)	22,000	22,000	22,000	22,000	22,000	22,000

Design Considerations. Mather Diversion damsite is located in a V-shaped valley with slide slopes of about 35 percent. Surficial geologic exploration indicates that the site is suitable for the diversion dam proposed.

Fresh granite is exposed in much of the channel while the abutments are covered with weathered rock and soil. Foundation preparation would consist of the removal of the soil and weathered rock on the abutments and minor shaping in the channel. The foundation would require a small amount of grouting to reduce percolation of water under the dam.

Concrete aggregate is available in limited amounts in alluvial deposits. Also available nearby are granite quarry sites for crushed rock aggregate.

Reservoir. Estimated average annual runoff of Middle Fork Tuolumne River at Mather Diversion damsite during the period from October 1, 1920, through September 30, 1955, is 40,300 acre-feet. The runoff drains a watershed of about 44 square miles. This runoff is presently unimpaired, and no future impairments are expected. The reservoir site is located on government-owned, unimproved land. The clearance of some timber and brush would be required.

Mather Diversion Dam was sized large enough to provide a means of diverting the flows of Middle Fork Tuolumne River into Mather ditch, then into Ackerson Creek, a tributory of the South Fork Tuolumne River, and then into Harden Flat Reservoir. A dam with a height of 20 feet was found to be adequate for this purpose.

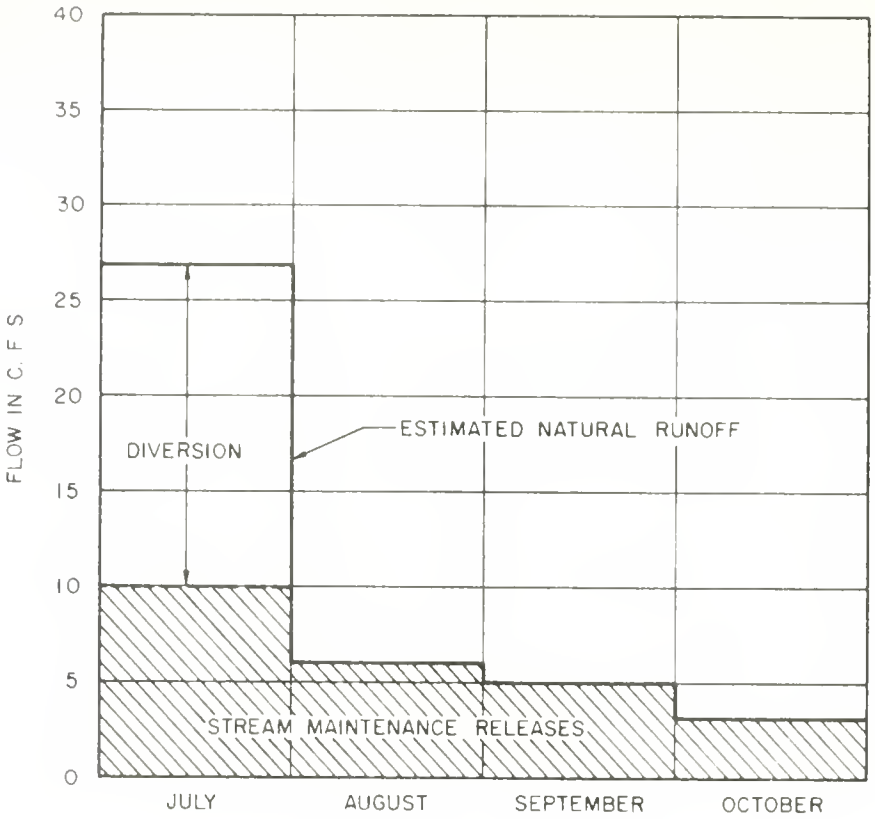
The dam would create a reservoir with a storage capacity of about 25 acre-feet. Mather ditch would convey the water from the diversion dam to Ackerson Creek. The diversion schedule would be as follows:

When inflow to Mather Diversion Reservoir is

- 10 second-feet or less, no diversions to be made by Mather ditch, all flows to river.
- Greater than 10 second-feet but less than 160 second-feet, first 10 second-feet to river, remainder to be diverted by Mather ditch.
- In excess of 160 second-feet, Mather ditch to divert its capacity of 150 second-feet, remainder to river.

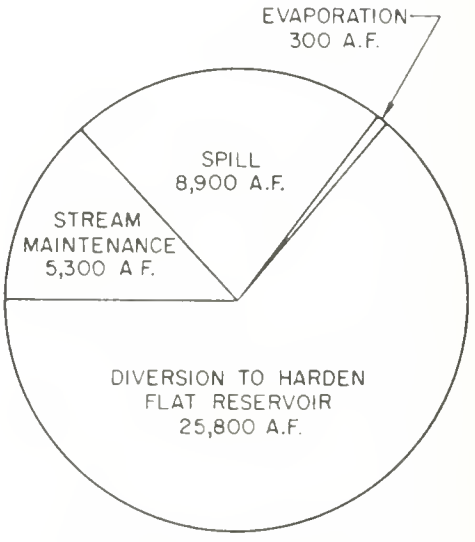
Figure 1, entitled "Disposition of Available Water Supply on Middle Fork Tuolumne River at Mather Diversion Dam During an Average Water Year," depicts the disposition of the available water supply at Mather Diversion Dam during an average runoff year. The figure also depicts how proposed releases of water through Mather Diversion Dam would affect the natural flows of Middle Fork Tuolumne River during months of low flow. Operation studies of the Mather Diversion Dam during the study period are presented in Table 25, entitled "Summary of Monthly Operations Studies of Mather Diversion."

Dam and Spillway. As designed for cost estimating purposes, Mather Diversion Dam would consist of a concrete overpour section rising 20 feet from an elevation of 4,640 feet in the streambed of the Middle Fork Tuolumne River. The total volume of concrete in the 200-foot-long weir would be about 2,400 cubic yards. The weir is designed to pass the 36,000 second-foot peak



ESTIMATED NATURAL RUNOFF
AND STREAM MAINTENANCE RELEASES

AVAILABLE WATER
SUPPLY
40,300 ACRE-FEET



DISPOSITION OF WATER
SUPPLY
40,300 ACRE-FEET

DISPOSITION OF AVAILABLE WATER SUPPLY
ON THE MIDDLE FORK TUOLUMNE RIVER
AT MATHER DIVERSION DAM
DURING AN AVERAGE RUNOFF YEAR

TABLE 25

SUMMARY OF MONTHLY OPERATION STUDIES OF MATHER DIVERSION DAMSITE
(In acre-feet)

Runoff Year	Estimated Inflow*	Water Releases and Losses (Operation)				
		Stream Flow Maintenance**	Diversion to Harden Flat Reservoir	Evaporation	Spill	Total
1920-21	44,500	6,200	32,200	300	5,800	44,500
22	61,600	5,700	32,600	400	22,900	61,600
23	43,500	6,500	30,300	300	6,400	43,500
24	10,700	4,900	5,800	-0-	-0-	10,700
25	46,000	6,000	29,300	200	10,500	46,000
1925-26	25,400	5,000	19,400	100	900	25,400
27	45,900	5,700	32,500	300	7,400	45,900
28	33,500	5,600	24,100	300	3,500	33,500
29	20,500	4,800	15,200	200	300	20,500
30	21,200	4,000	16,500	100	600	21,200
1930-31	9,300	3,500	5,800	-0-	-0-	9,300
32	46,500	5,200	30,600	300	10,400	46,500
33	21,700	4,000	14,700	100	2,900	21,700
34	12,200	4,300	7,800	100	-0-	12,200
35	52,700	5,300	28,900	200	18,300	52,700
1935-36	50,400	5,300	31,900	300	12,900	50,400
37	49,800	4,800	29,700	400	14,900	49,800
38	100,600	6,100	50,100	600	43,800	100,600
39	19,300	5,900	13,200	200	-0-	19,300
1939-40	46,200	5,000	30,800	400	10,000	46,200

(Continued)

TABLE 25 (Continued)

SUMMARY OF MONTHLY OPERATION STUDIES OF MATHER DIVERSION
(In acre-feet)

Runoff Year	Estimated Inflow*	Water Releases and Losses (Operation)				
		Stream Flow Maintenance**	Diversion to Harden Flat Reservoir	Evaporation	Spill	Total
1940-41	61,900	5,800	36,300	300	19,500	61,900
42	64,800	6,300	39,700	400	18,400	14,800
43	58,600	5,900	40,600	400	11,700	58,600
44	29,900	5,200	19,500	200	5,000	29,900
45	49,800	6,000	36,500	300	7,000	49,800
1945-46	51,300	6,400	33,400	300	11,200	51,300
47	23,800	5,500	17,500	200	600	23,800
48	29,900	4,900	19,400	300	5,300	29,900
49	25,500	4,200	18,300	200	2,800	25,500
50	31,500	4,800	21,300	200	5,200	31,500
1950-51	58,100	5,900	40,300	300	11,600	58,100
52	79,000	6,300	39,700	400	32,600	79,000
53	31,200	5,800	23,400	300	1,700	31,200
54	33,200	5,100	20,200	300	7,600	33,200
1954-55	21,500	5,100	14,500	100	1,800	21,500
TOTAL	1,411,500	187,000	902,000	9,000	313,500	1,411,500
35-YEAR AVERAGE	40,300	5,300	25,800	300	8,900	40,300

*Estimated natural runoff Middle Fork Tuolumne River at Mather Diversion Damsite.
**For maintenance and enhancement of fish and wildlife.

flow of the maximum probable flood with a depth of 14 feet of water over the lip of the dam.

Outlet Works. Mather Diversion Dam would have two outlet works. A gate valve in a 12-inch diameter pipe would be used to release stream maintenance flows through the dam. The second control structure, a 6-foot-square slide gate, would be used to regulate flows into Mather ditch.

A summary of the estimated capital costs of the Mather Diversion Dam and appurtenances is included in Table 26, entitled "Estimated Capital Costs of Harden Project Dams and Reservoirs."

Mather Ditch

Mather ditch would consist of about 16,000 feet of open canal and 2,500 feet of flume. Its capacity would be 150 cubic feet per second. From Mather Diversion Dam, the conduit would extend southerly about 3.5 miles to its outlet on Ackerson Creek, 1.3 miles above Ackerson Creek's confluence with the South Fork of the Tuolumne River. The alignment selected for the Mather ditch would pass through heavy to moderate tree and brush cover.

The canal would be built through an area underlain by granitic rocks which are in some places exposed and at other places covered by decomposed granite. In the decomposed granite areas, the trapezoid-shaped canal would have a 4-foot bottom width, a 3.8-foot depth, and $1\frac{1}{2}$:1 side slopes. In the hard rock areas, the canal would have a 4-foot bottom width, a 4.4-foot depth, and $\frac{1}{2}$:1 side slopes. The canal would be concrete-lined throughout, would have a gradient of 0.0005, and would have a design velocity of about 4 feet per second.

TABLE 26

ESTIMATED CAPITAL COSTS OF HARDEN PROJECT DAMS AND RESERVOIRS
(Based on prices prevailing in fall 1961)

Features	Mather Diversion		Lost Claim Forebay	
	Amount	Cost	Amount	Cost
Dam				
Excavation and stripping	1,000 c.y.	$ 2,800	113,000 c.y.	$198,000
Concrete	2,360 c.y.	129,600		
Grouting	200 l.f.	2,600		
Subtotals		$135,000		$198,000
Spillway				
Lump sum				$ 2,000
Subtotal				$ 2,000
Outlet works				
Lump sum		$ 7,000		
Subtotal		$ 7,000		
Other items				
Lump sum		$ 4,000		
Total all items		$146,000		$200,000
Contingencies: 15%		22,000		30,000
Subtotals		$168,000		$230,000
Engineering: 15%		25,200		34,500
Subtotals		$193,200		$264,500
Interest during construction		2,800		3,500
TOTAL CAPITAL COSTS		$196,000		$268,000

(Continued)

TABLE 26 (Continued)

ESTIMATED CAPITAL COSTS OF HARDEN PROJECT DAMS AND RESERVOIRS
(Based on prices prevailing in fall 1961)

Features	Harden Flat Amount	Harden Flat Cost	Burch Meadow Amount	Burch Meadow Cost
Dam				
Excavation and stripping	177.000 c.y.	$ 190,100	47,000 c.y.	$ 43,200
Embankment				
Rock fill	910,000 c.y.	720,500	--	--
Impervious	600,000 c.y.	443,700	230,400 c.y.	273,900
Transition, etc.	133,000 c.y.	201,000	36,800 c.y.	101,600
Grouting	l.s.	164,700	l.s.	31,300
Subtotals		$1,720,000		$450,000
Spillway				
Excavation	82,000 c.y.	$ 150,000	9,300 c.y.	$ 9,300
Concrete	5,000 c.y.	300,000	600 c.y.	29,100
Reinforcing steel	37,000 lb.	50,000	3,100 lb	4,600
Subtotals		$ 500,000		$ 43,000
Outlet works				
Lump sum		$ 380,000		$ 47,000
Unlisted items				
Lump sum		--		38,000
Relocation				
Lump sum		--		104,000
Reservoir				
Land and improvements		277,000		32,000
Clearing	430 ac.	53,000	188 ac.	11,000
Subtotals		$ 330,000		$ 43,000
Total all items		$2,930,000		$725,000
Contingencies: 15%		$ 439,500		$108,800
Subtotals		$3,369,500		$833,800
Engineering and administration: 15%		505,400		125,100
Subtotals		$3,874,900		$958,900
Interest during construction		155,100		21,100
TOTAL CAPITAL COSTS		$4,030,000		$980,000

Two sections of flume are proposed: one section would be on the side hill at the beginning of the ditch; the other section would be an elevated flume over a gully in the middle reach of the ditch. The flumes would have a diameter of 7 feet and a gradient of 0.004. Water would flow at a velocity of about 9 feet per second.

A summary of the estimated capital costs of the Mather Ditch is included in Table 27, entitled "Estimated Capital Cost of Harden Project Conduits."

Harden Flat Dam and Reservoir

The proposed Harden Flat Dam would be constructed in a steep, narrow canyon carved by the South Fork Tuolumne River approximately one-half mile west of the community of Harden Flat. Present access to the damsite is by a footpath about 1,000 feet in length, starting at a sawmill located adjacent to State Highway 120. The dam would be located in Sections 35 and 36, Township 1 South, Range 18 East, MDB&M. Surficial geologic examination indicates that the site is probably suitable for a dam of the height proposed. Topography of the Harden damsite was mapped by the Department of Water Resources* to the scale of 1 inch equals 100 feet, with a contour interval of 10 feet. The reservoir was mapped to a scale of 1 inch equals 300 feet, with a contour interval of 10 feet.

* This map was an extension of the U.S. Bureau of Reclamation map made in 1947 to the scale of 1 inch equals 50 feet and was made using photogrammetric methods.

TABLE 27

ESTIMATED CAPITAL COST OF HARDEN PROJECT CONDUITS
(Based on prices prevailing in fall 1961)

Feature	Mather Ditch		Golden Rock Ditch		Burch Meadow Conduit	
	Amount	Cost	Amount	Cost	Amount	Cost
Access road	3.6 mi.	$28,000	9.5 mi.	$95,000	3.1 mi.	$24,200
Excavation	27,600 c.y.	36,000	229,000 c.y.	236,000	5,800 c.y.	9,400
Trimming	32,000 s.y.	19,000	6,000 s.y.	48,000	12,500 s.y.	6,900
Gunite lining	2,700 c.y.	81,000	7,900 c.y.	198,000	900 c.y.	27,000
Flume	2,500 l.f.	125,000	6,270 l.f.	332,000		
Siphon			470,000 lb.	164,000	68,200 lb.	24,600
Canal structures	16	25,000	10	65,000	5	9,400
Subtotal		$314,000		$1,138,000		$101,500
Contingencies: 15%		47,100		170,700		15,200
Subtotal		$361,100		$1,308,700		$116,700
Engineering: 15%		54,200		196,300		17,500
Subtotal		$415,300		$1,505,000		$134,200
Interest during construction		7,700		30,000		2,800
TOTAL CAPITAL COST		$423,000		$1,535,000		$137,000

Design Considerations. The damsite is located on quartz-mica schist and quartzite rocks of the Calaveras group. Areas of numerous rock outcrops or thin soil development account for about one half the area of the damsite on the right abutment and for about two tenths of the area on the left abutment. Areas of thicker residual soil or slopewash account for one quarter of the right abutment area and six tenths of the left abutment area. Areas of talus and slopewash account for the remaining one fourth of the right abutment and two tenths of the left abutment. Most of the channel area is covered by alluvium. Three smaller shear zones are visible in the right abutment. Where visible, the bedrock is not weathered to a great depth and all varieties of rock involved, where fresh, appear to be strong enough to support the dam. The alluvial materials, however, are unconsolidated and unstable. The sheer zones are small and should pose only a minor problem.

Foundation preparation for the right abutment would involve removing loose debris to an average depth of seven feet, shaping to eliminate large jutting outcrops, and trenching and grouting of the shear zone.

Foundation preparation in the channel would involve removal of all alluvium to an average depth of ten feet and treatment of the shear zones by trenching and grouting.

Foundation preparation of the left abutment would involve removal of the loose debris to an average depth of ten feet and shaping of the foundation to remove jutting outcrops. Moderate grouting would be required to reduce percolation of water under the dam.

Since large areas of the abutments are covered by colluvium and only surficial geology is available, it is recommended that detailed exploration be conducted to assure that serious foundation problems do not exist.

Materials suitable for use in an earthfill or rockfill dam exist close to the site. Potential quarry sites in quartz-mica schist exist in the spillway area and immediately downstream. Power augering was used to sample a large source of impervious decomposed granite in the hill slopes of the reservoir. The limited testing indicated that probably a sufficient source of a nonplastic, silty sand (SM) material is available as impervious or semipervious material to build the dam. Filter materials and concrete aggregate could be obtained from alluvium in the South Fork of the Tuolumne River. It appears that adequate amounts of these materials could be obtained within about one mile of the damsite.

Reservoir. Estimated natural runoff of South Fork Tuolumne River at Harden damsite is 63,500 acre-feet annually. The runoff drains a watershed of about 82 square miles. Present impairments of runoff are minor and it is anticipated that future impairments will remain minor. In addition to the natural runoff of South Fork Tuolumne River about Harden damsite, an estimated average of 25,800 acre-feet would be diverted from the Middle Fork Tuolumne River annually, by the Mather Diversion Dam and Mather ditch.

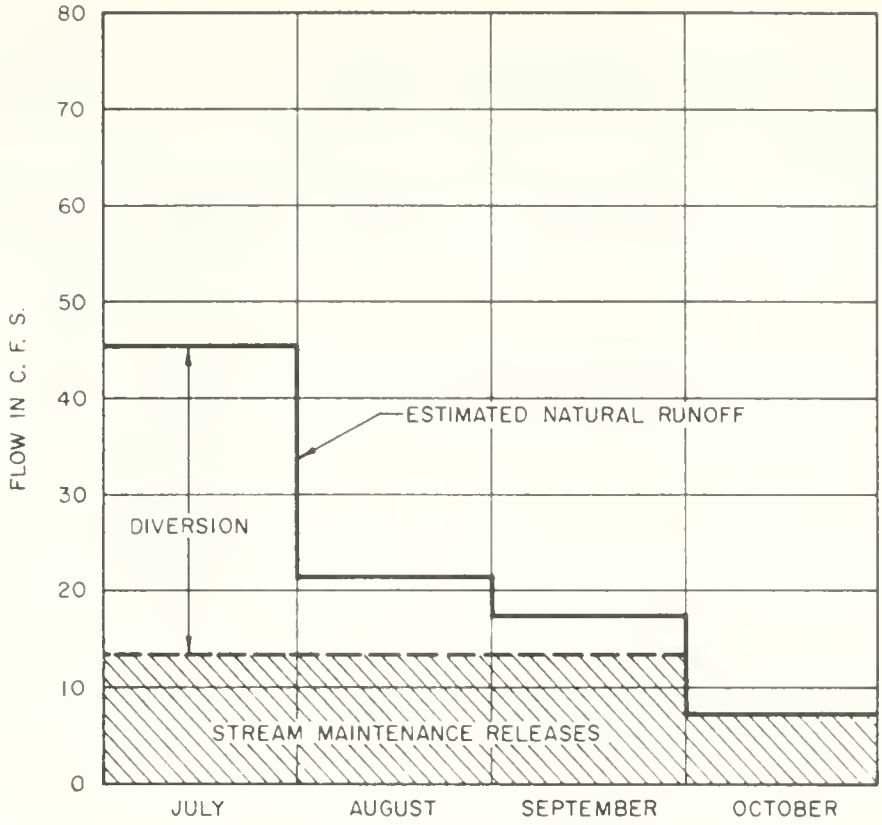
The reservoir would inundate approximately 430 acres of privately owned meadow and forest land. Improvements presently

located within the proposed reservoir site include a summer lodge, cabins, a service station-market, and a sawmill. Clearing of second-growth timber throughout a major portion of the reservoir area would be required.

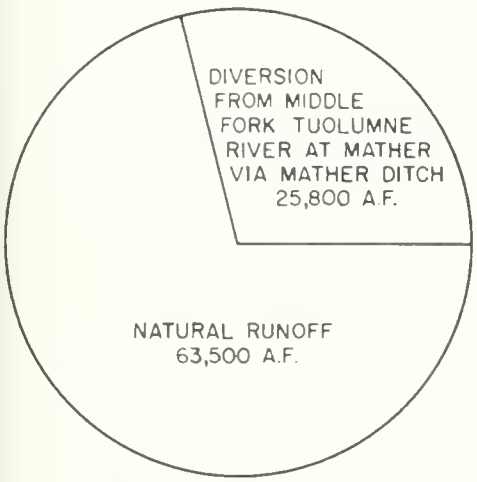
Economic analysis shows that Harden Flat Reservoir should be sized to have an active storage capacity of 40,800 acre-feet to maximize the net benefits derived from power. With the addition of inactive storage, the gross storage required in Harden Flat Reservoir is 42,000 acre-feet.

Figure 2, entitled "Disposition of Available Water Supply on South Fork Tuolumne River at Harden Flat Dam During an Average Runoff Year," compares releases of water from Harden Flat Reservoir and natural runoff of the South Fork Tuolumne River. A summary of monthly operation studies is presented in Table 28, entitled "Summary of Monthly Operation Studies at Harden Flat Reservoir."

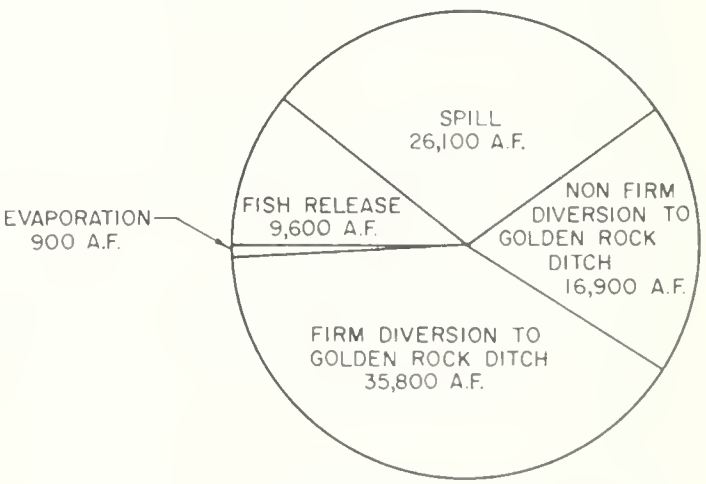
Dam. Harden Flat Dam would be an earth and rockfill structure rising 235 feet from streambed elevation of 3,435 feet. The crest would be 750 feet in length and 30 feet in width. The dam would have upstream and downstream slopes of 2:1, and would contain about 1,640,000 cubic yards of earth and rock. Plate 7, entitled "Harden Flat Dam on South Fork Tuolumne River," shows the general features of the proposed dam.



ESTIMATED NATURAL RUNOFF
AND STREAM MAINTENANCE RELEASES



AVAILABLE WATER
SUPPLY
89,300 ACRE-FEET



DISPOSITION OF WATER
SUPPLY
89,300 ACRE-FEET

DISPOSITION OF AVAILABLE WATER SUPPLY
ON THE SOUTH FORK TUOLUMNE RIVER
AT HARDEN FLAT DAM
DURING AN AVERAGE RUNOFF YEAR

TABLE 28

SUMMARY OF MONTHLY OPERATION STUDIES AT HARDEN FLAT RESERVOIR
(In acre-feet)

Runoff year	Storage on first of October	Inflow: From Mather Diversion	Inflow: Natural*	Inflow: Total	Water releases and losses (Operation): Streamflow maintenance	Diversions to Golden Rock Ditch: Firm yield	Diversions to Golden Rock Ditch: Non firm yield	Evaporation	Spill
1920-21	27,800	32,200	69,800	102,000	9,300	35,800	19,100	900	36,100
22	32,600	32,600	97,200	129,800	8,800	35,800	16,800	900	63,500
23	32,000	30,300	68,400	98,700	10,400	35,800	19,100	900	33,100
24	11,400	5,800	18,600	24,400	8,500	35,800	0	700	0
25	29,100	29,300	59,100	88,400	10,200	35,800	12,300	900	11,500
1925-26	25,900	19,400	35,600	55,000	9,400	35,800	7,200	900	4,200
27	28,800	32,500	69,800	102,300	10,000	35,800	19,200	900	33,500
28	26,500	24,100	45,300	69,400	9,800	35,800	13,400	900	11,900
29	26,600	15,200	30,300	45,500	8,800	35,800	0	800	0
1929-30	27,700	16,500	28,700	45,200	7,200	35,800	200	900	0
31	5,100	5,800	15,100	20,900	7,200	35,800	0	600	0
32	29,500	30,600	67,000	97,600	8,400	35,800	12,400	900	15,700
33	28,100	14,700	33,400	48,100	7,800	35,800	5,000	900	0
34	12,800	7,800	20,500	28,300	7,200	35,800	0	700	0
1934-35	29,600	28,900	81,300	110,200	9,500	35,800	14,800	900	32,300
36	29,200	31,900	71,900	103,800	9,900	35,800	25,300	900	31,400
37	29,500	29,700	82,300	112,000	10,000	35,800	23,700	900	41,200
38	34,500	50,100	174,100	224,200	10,600	35,800	37,700	900	134,300
39	25,100	13,200	35,900	49,100	10,000	35,800	11,200	900	600

(Continued)

TABLE 28 (Continued)

SUMMARY OF MONTHLY OPERATION STUDIES AT HARDEN FLAT RESERVOIR
(In acre-feet)

Runoff year	Storage on first of October	Inflow			Water releases and losses (Operation)				
		From Mather Diversion	Natural*	Total	Streamflow maintenance	Diversions to Golden Rock Ditch: Firm yield	Diversions to Golden Rock Ditch: Non firm yield	Evaporation	Spill
1939-40	28,100	30,800	79,400	110,200	10,400	35,800	22,100	900	38,300
41	32,500	36,300	108,200	144,500	10,700	35,800	33,100	900	60,600
42	33,600	39,700	106,800	146,500	10,800	35,800	34,400	900	63,500
43	29,900	40,600	101,400	142,000	10,800	35,800	40,200	900	57,900
44	29,200	19,500	51,400	70,900	10,500	35,800	12,400	900	12,000
1944-45	29,800	36,500	86,600	123,100	10,500	35,800	33,100	900	42,100
46	29,000	33,400	76,000	109,400	10,700	35,800	35,200	900	27,600
47	26,000	17,500	39,200	56,700	9,800	35,800	11,200	900	2,000
48	29,200	19,400	42,700	62,100	10,000	35,800	6,000	900	6,300
49	27,900	18,300	40,000	58,300	9,200	35,800	9,800	900	3,900
1949-50	27,900	21,300	44,900	66,200	9,500	35,800	10,600	900	9,400
51	28,300	40,300	87,600	127,900	10,400	35,800	42,700	900	37,800
52	34,400	39,700	123,000	162,700	10,700	35,800	29,600	900	79,500
53	29,400	23,400	47,400	70,800	10,400	35,800	18,500	900	10,200
54	28,300	20,200	51,300	71,500	9,700	35,800	14,300	900	11,900
55	27,900	14,500	33,200	47,700	9,300	35,800	2,100	900	0
TOTALS	--	902,000	2,223,400	3,125,400	336,400	1,253,000	592,700	30,700	913,000
35-YEAR AVERAGE		25,800	63,500	89,300	9,600	35,800	16,900	900	26,100

*Estimated natural runoff of South Fork Tuolumne River at Harden Flat Damsite

Spillway. An ungated side-channel spillway with a concrete ogee weir 300 feet in length and with a partially lined chute would be constructed in the right abutment. It would be designed to pass a flood peak of 58,000 second-feet, which represents the discharge resulting from the maximum probable flood. The maximum depth of water above the spillway lip would be 14 feet. An additional one foot of freeboard would be provided. The spillway would pass the 23,000 second-feet peak flow of the standard project flood with seven feet of water above the spillway lip and with eight feet of freeboard. Spilled water would be returned to the main river channel downstream from the toe of the dam.

Outlet Works. Water would flow 650 feet through a seven-foot diameter diversion tunnel to an emergency control structure in the tunnel plug located under the crest of the dam. There, the flow would pass through a 48-inch diameter slide gate, and then through 500 feet of 48-inch diameter steel pipe to the tunnel exit, where the flow would be regulated by a 42-inch butterfly valve in the headworks of Golden Rock ditch. For stream maintenance releases, a bypass will be provided from the 48-inch-diameter pipe near the end of the tunnel to the South Fork Tuolumne River through an 18-inch-diameter pipe controlled by an 18-inch Howell-Bunger valve.

A summary of estimated capital costs of Harden Flat Dam and Reservoir is included in Table 26, entitled "Estimated Capital Costs of Harden Project Dams and Reservoirs."

Golden Rock Ditch

Golden Rock ditch would consist of about 42,000 feet of open canal, 2,000 feet of flume, and 2,000 feet of inverted siphon. Its capacity would be 165 second-feet. From Harden Flat Reservoir, the conduit would extend about 8.7 miles west to Lost Claim Forebay. The alignment would generally follow the now abandoned Golden Rock water ditch. Acquisition should be relatively uncomplicated since the rights-of-way for the abandoned ditch are still held by Tuolumne County.

The canal would have a concrete-lined trapezoidal section, with a gradient of 0.0005. The velocity of flow at design capacity would be about 4.5 feet per second. In rock, the canal would have a depth of 4.2 feet, a freeboard of 1 foot, a bottom width of 6 feet, and side slopes of $\frac{1}{2}$:1. In common excavation, the canal would have a depth of 3.7 feet, a freeboard of 1 foot, a bottom width of 5 feet, and side slopes of $1\frac{1}{4}$:1.

The semicircular flume would have a 9.5-foot diameter and a gradient of 0.0007. The velocity of flow at design capacity would be about five feet per second.

Golden Rock ditch would pass under State Highway 120 in an inverted siphon. The inverted siphon would be a 60-inch diameter pipe, 2,000 feet in length, supported by piers and saddles except for the cut and cover section under the highway. The hydraulic gradient would be 0.0024 and the velocity of flow at design capacity would be about eight feet per second.

A summary of estimated capital cost of Golden Rock ditch is included in Table 27, entitled "Estimated Capital Cost of Harden Project Conduits."

Lost Claim Forebay

Lost Claim Forebay would be formed by excavating a reservoir, entirely in-cut, out of a mountain top near Lost Claim Campground.

Present access to the site is by two miles of unpaved road from Lost Claim Campground which is located adjacent to State Highway 120. The forebay would be located in Section 25, Township 1 North, Range 18 East, MDB&M. Topography of the site was obtained from the United States Geological Survey's $7\frac{1}{2}$-minute quadrangle, "Jawbone Ridge, California," scale, 1:24,000; contour interval, 50 feet.

Bedrock at the Lost Claim Forebay site is a schist which is covered by eight feet of overburden. The rock would require drilling and blasting.

Lost Claim Forebay would have a storage capacity of 50 acre-feet. This capacity is sufficient to allow time for releases from Harden Flat Reservoir to reach the forebay (in case of a sudden power demand) before the forebay would be emptied. Water leaving the forebay would flow 500 feet in the last section of the Golden Rock ditch to the entrance of the Lost Claim Powerhouse penstocks or would flow through Burch Meadow Conduit to Burch Meadow Reservoir.

A summary of estimated capital costs of Lost Claim Forebay is included in Table 26, entitled "Estimated Capital Costs of Harden Project Dams and Reservoirs."

Lost Claim Powerhouse

Lost Claim Powerhouse would have an installed power capacity of 22,000 kilowatts. The welded steel penstock to the powerplant would be 3,360 feet long. Its diameter would decrease from 54 inches at its inlet to 42 inches at its outlet in the powerplant. The powerplant, operating under an average static head of 2,000 feet, would consist of a single power unit. Estimated capital costs of the Lost Claim Powerhouse are summarized in Table 29, entitled "Estimated Capital Costs of the Lost Claim Powerhouse of the Harden Project."

TABLE 29

ESTIMATED CAPITAL COSTS OF THE LOST CLAIM POWERHOUSE OF THE HARDEN PROJECT

(Based on prices prevailing in fall 1961)

Feature	Quantity	Cost
Penstock	1,760,000 lbs.	$ 810,000
Powerplant		1,960,000
Subtotal		$2,770,000
Contingencies: 15%		415,000
Subtotal		$3,185,000
Engineering and administration: 15%		478,000
Subtotal		$3,663,000
Interest during construction		72,000
TOTAL		$3,735,000

Burch Meadow Conduit

Burch Meadow conduit would consist of about 13,300 feet of open canal and 3,100 feet of inverted siphon. Its capacity would be 10 second-feet. From Lost Claim Forebay, the conduit would extend about 3.1 miles west to a point on Big Creek where the water can flow by natural channels into Burch Meadow Reservoir. Since the selected alignment goes through an area of light trees and brush and encounters no developments, the cost of acquisition should be moderate.

The canal would have a concrete-lined trapezoidal section with a gradient of 0.0005 and a velocity of 2.05 feet per second at design capacity. In rock, the canal would have a depth of 1.5 feet, a freeboard of 0.5 foot, a bottom width of 2.5 feet, and side slopes of $\frac{1}{2}$:1. In common excavation, the canal would have a depth of 1.33 feet, a freeboard of 0.5 feet, a bottom width of 1.75 feet, and side slopes of $1\frac{1}{2}$:1.

An inverted siphon 2,400 feet in length would be required to cross a valley just south of Lost Claim Forebay. Seven hundred feet of inverted siphon would be required to cross State Highway 120. Both sections of the inverted siphon would be 14-inch pipe, supported by piers and saddles except for the short length of cut and cover section under the highway. The velocity of flow at design capacity would be 10 feet per second and the hydraulic gradient would be 0.040.

Estimated capital costs of Burch Meadow Conduit are summarized in Table 27.

Burch Meadow Reservoir

Burch Meadow damsite is located seven miles southeast of Groveland on Big Creek, a tributary of the Tuolumne River. The Smith Station Road crosses the axis of the dam 2,000 feet from its intersection with State Highway 120. The site is situated within a small narrow canyon carved into the low northeast trending Sierra foothills by Big Creek just below Burch Meadow. The site is located in Section 32, Township 1 South, Range 17 East, MDB&M. Surficial geologic exploration indicates that the site would suit a dam of the height considered in this investigation. Topography of this dam and reservoir site was mapped at a scale of 150 feet to the inch and a contour interval of 5 feet by the Department of Water Resources. A portion of this map at the damsite was enlarged to a scale of 50 feet to the inch.

Design Considerations. Since only surficial geologic exploration was undertaken at this site and since very few outcrops of bedrock occur in this area, foundation problems may exist which are not now known. Bedrock at the site is composed of interbedded quartz biotite schist, hornfels, and related metamorphic rocks tentatively assigned to the Calaveras group. The well-defined foliation of these rocks strikes parallel to the stream channel and dips about 40° into the left abutment. Both the left and right abutments are covered entirely by an overburden of slope wash and residual soil. The 185-foot channel section has a maximum width of 20 feet of flowing water and is covered almost completely by an alluvium consisting of subrounded to platy gravels intermixed with sands and fines.

Foundation treatment of the right abutment would consist of stripping all overburden and the more fractured and weathered rock to an average depth of 8 feet, and extending to an average depth of 13 feet under the cutoff.

Foundation treatment in the channel would consist of removal of all alluvium to an average depth of about 8 feet with some minor shaping of irregularities. A small cutoff trench may also be required.

Foundation treatment of the left abutment would consist of stripping off the overburden and the more fractured and weathered rock to an average depth of 7 feet under the dam and to an average depth of 10 feet when a cutoff trench is required.

Moderate amounts of grouting to 20 or 30 feet below the foundation would be required to reduce percolation under the dam.

Exploration for construction materials was limited to surficial geologic mapping. The following sources of construction materials were considered:

Impervious Fill

1. Unlimited amounts of intensely weathered Calaveras schist which has been reduced to a micaceous sandy silt are available within one-half mile of the axis. This material is believed to have little shearing strength, little or no cohesion, and in general would be a rather poor construction material.

2. Tertiary sediments consisting of well-rounded cobbles, gravel, sand, and fines are available within one and one-half miles of the damsite. About 75 percent of the coarse aggregates in the deposit are intensely weathered. Based on information from other state and federal agencies, extensive processing would be required to produce satisfactory fill material from these sediments.

3. Decomposed granite of suitable quality is available in Big Oak Flat about ten miles away.

Rockfill

Limited amounts of fairly massive and generally unweathered metamorphic rocks occur in local outcrops within one mile of the site. Excavation of this material may result in extensive waste.

Concrete Aggregate

Concrete aggregate is not available locally. Tuolumne River near Jacksonville (19 miles by State Highway 120) is the nearest likely source.

Reservoir. Estimated average annual natural runoff of Big Creek at Burch Meadow damsite is 1,700 acre-feet. The runoff drains a watershed of about 2.65 square miles. At present, there are no significant impairments to this natural flow. Future developments for recreation and domestic purposes will probably be minor. In addition to the natural runoff of Big Creek above the Burch Meadow damsite, an estimated 1,800 acre-feet annually would be imported via the Golden Rock ditch from Harden Flat Reservoir.

The Burch Meadow Reservoir would inundate about 188 acres of privately and federally owned meadow and forest land. Improvements presently located within the proposed reservoir site include a gasoline station, three large cabins, a home, and several out-buildings. Clearing should not be extensive since most of the reservoir area has been cleared for cattle grazing.

Economic studies show that Burch Meadow Reservoir should be sized to provide maximum recreational benefits. Maximum recreational benefits accrue when the waterline is near the existing tree line. Thus, the normal pool elevation was selected at 3,044 feet. This selection results in a reservoir with a capacity of 3,550 acre-feet.

Dam. Burch Meadow Dam would be a homogeneous earthfill structure rising 76 feet from streambed elevation of 2,976 feet, with an inclined chimney drain and a horizontal downstream blanket drain. The crest would be 700 feet in length and 30 feet in width. The dam would have a downstream slope of 2½:1, and upstream slope of 4:1, and would contain about 276,000 cubic yards of material. This type dam was selected as best suiting the site after considering the construction materials available. Plate 8, entitled "Burch Meadow Dam on Big Creek," shows the general features of the proposed dam.

Spillway. An ungated chute spillway with a concrete ogee weir 50 feet in length and a concrete-lined chute would be constructed on the right abutment. It would be designed to pass a flood with a peak flow of 4,700 second-feet which represents the estimated maximum probable flood. The maximum depth of water above the lip of the spillway would be six feet; an additional two feet of freeboard would be provided. Spilled water would return through a gully to the main stream of Big Creek below the toe of the dam.

Outlet Works. Water for distribution to the project service areas would pass through a 36-inch diameter reinforced concrete pipe placed in a trench excavated under the dam. Emergency control would be provided by a three-foot diameter slide gate in the trash-rack structure upstream, and regulation would be provided by a three-foot butterfly valve at the exit.

A summary of estimated capital costs of Burch Meadow Reservoir is included in Table 26, entitled "Estimated Capital Costs of Harden Project Dams and Reservoirs."

Costs and Benefits

The costs and benefits of the Harden Project are discussed in the following pages in terms of average annual equivalent, taxes foregone, and present worth.

The average annual equivalent is used to establish, for comparative purposes, a uniform annual cost or benefit throughout the 50-year repayment period. The average annual equivalent cost of the Harden Project equals the annual cost of operation and maintenance added to the product of the capital cost and a capital recovery factor of 0.04655. This particular capital recovery factor when multiplied by a present debt gives the uniform annual end-of-year payment necessary to repay the debt in 50 years with interest at four percent.

Taxes lost when a public rather than a private agency develops power are sometimes considered as taxes foregone. When studies were made under this investigation for determining the economic justification of a proposed hydroelectric power development, taxes foregone were considered as a project cost. The yearly amounts of taxes which would have been paid by a private company are included in this report as taxes foregone.

From the viewpoint of the investor, the present worth of a future expenditure or series of expenditures is the present

money value necessary to secure the return of that future expenditure with interest at a given rate; in this case four percent. The present worth of the operation and maintenance costs of the Harden Project is the product of the average annual cost of operation and maintenance times 21.482 (the reciprocal of the capital recovery factor).

Costs. For a 50-year repayment period, the average annual equivalent cost of the Harden Project, including taxes foregone, would be $1,292,400. The total economic cost of the project would be $27,762,000. This cost represents the capital cost plus the present worth of operation and maintenance costs plus taxes foregone.

Included in the above costs are the eight proposed major features and the cost of public recreation facilities which would be built along the shores of the Harden Project reservoirs.

Recreation facilities would be constructed in stages planned to accommodate the predicted increased use during the 50-year repayment period of the project. Although private recreation facilities probably would be constructed near the proposed reservoirs, the justification for public investment is restricted to those benefits derived from public facilities. To encourage full development, however, public funds would provide such basic facilities as reservoir access roads, public campgrounds, drinking water, and sanitary facilities. In the public interest, all potential recreation lands under private ownership adjacent to the reservoir sites would be purchased. Use permits would be obtained

for such lands now under federal ownership. Operational policies would determine both the administrative procedures to be followed and the allocation of land for private and public use.

Benefits. The Harden Project would produce domestic water, recreation, and power benefits.

The present worth of the domestic water benefits attributable to the Harden Project throughout the 50-year repayment period was estimated to be $700,000. The corresponding average annual equivalent benefit was established to be $32,600.

The present worth of the recreation benefits attributable to the Harden Project throughout the 50-year repayment period was estimated to be $19,840,000. The corresponding average equivalent benefit was estimated to be $923,600.

The present worth of the power benefits attributable to the Harden Project throughout the 50-year repayment period was estimated to be $17,620,000. The corresponding average annual equivalent benefit was estimated to be $820,200.

In summary, the present worth of domestic, recreation, and power benefits attributable to the Harden Project would total $38,160,000. The corresponding total average annual equivalent benefit would be $1,776,000.

Benefit-Cost Ratio. The benefit-cost ratio of the Harden Project is estimated to be 1.37 to 1. The Harden Project is thus justifiable from an economic standpoint. Table 30, entitled "Harden Project Costs, Benefits, and Benefit-Cost Ratio," summarizes estimated costs and benefits and presents the benefit-cost ratio of the project.

TABLE 30

HARDEN PROJECT COSTS, BENEFITS, AND BENEFIT-COST RATIO

Feature	Annual costs: Capital recovery*	Annual costs: Operation and maintenance**	Annual costs: Totals (average annual equivalents)	50-year repayment period costs: Capital cost	50-year repayment period costs: Present worth of operation and maintenance	50-year repayment period costs: Totals
Mather Diversion	9,100	1,600	10.700	196,000	34.000	230,000
Mather Ditch	19,700	5,600	25.300	423,000	120 000	543.000
Harden Flat Reservoir	187,600	24,300	211,900	4,030,000	522.000	4,552.000
Golden Rock Ditch	71,500	20,600	92,100	1,535,000	443.000	1,978,000
Lost Claim Forebay	12,500	2,400	14,900	268,000	52,000	320,000
Lost Claim Powerplant	173,900	152,700	326,600	3,735,000	3.280,000	7,015,000
Burch Meadow Conduit	6,400	2,100	8,500	137,000	45,000	182,000
Burch Meadow Reservoir	45,600	4,600	50.200	980,000	99,000	1,079,000
Recreation Facilities	92,200	273,000	365,200	1,981,000***	5,865,000	7.846.000
TOTALS	618,500	486,900	1,105.400	13.285,000	10.460,000	23,745,000
Taxes foregone			187,000			4,017,000
TOTALS			1,292,400			27,762.000

Item	Benefits: Average annual equivalents	Benefits: Present worth	Benefit-cost ratio
Domestic	32,600	700,000	
Recreation	923,600	19,840,000	1.37 to 1
Power	820,200	17,620,000	
TOTALS	1,776,400	38,160,000	

*Interest at 4 percent throughout the 50-year repayment period.

**Includes replacement and general expense.

***Recreation facilities would be built in stages to accommodate increased use during the 50-year repayment period. This figure, therefore, represents the present worth.

Payment Capacity. Inclusion of irrigation as a purpose in the Harden Project under present price-cost conditions is not economically justified since the cost of incorporating irrigation features into the project exceeds the irrigation benefits and the payment capacity of the lands to be irrigated. The amount that water users would be able to pay for water delivered to their headgates in the Groveland Unit was $41 per acre for land planted to orchard and $20 per acre for land used as improved pasture, with a weighted average of $22.50 per acre, or $6.60 per acre-foot of water. No other project was found which could include irrigation as an economically justified project purpose.

The Groveland Project

The Groveland Project was found to be sufficiently inferior to the Harden Project to justify its elimination from further consideration as an immediate solution to the water supply problems of Southern Tuolumne County. The Groveland Project was designed to serve the same purposes as the Harden Project, but differs from that project in the location of its major storage reservoir and in the location of its powerhouse. These changes result in changes in the size and location of the associated conduits. The effects downstream are approximately the same for both projects.

Both projects supply the same amount of domestic water (about 1,800 acre-feet annually) to the same service area for a benefit of $700,000. However, where the Harden Project would provide 22,000 installed kilowatts and produce 90,700,000 kilowatt-hours of energy annually, the Groveland Project would have only 16,100 kilowatts of

installed capacity and produce only 57,800,000 kilowatt-hours of energy. This results in a power benefit of $17,620,000 for the Harden Project versus a power benefit of $12,320,000 for the Groveland Project.

The Harden Project would attract people for a total of 26,200,000 visitor-days during the 50-year repayment period. These 26,200,000 visitor-days are distributed as follows: 13,600,000 visitor-days to Burch Meadow Dam; 8,600,000 visitor-days to Harden Flat Dam; and 4,000,000 visitor-days to use of cabins. The Groveland Project would have a total of 31,000,000 visitor-days in the same period. These 31,000,000 visitor-days are distributed as follows: 13,600,000 visitor-days to Burch Meadow Dam; 10,000,000 visitor-days to Harden Diversion; 3,400,000 visitor-days to Groveland Dam; and 4,000,000 visitor-days to cabin use. This results in a recreational benefit of $19,840,000 for the Harden Project, and $23,137,000 for the Groveland Project.

With the total cost of the Groveland Project at $31,700,000 and its total benefits at $36,157,000 the benefit-cost ratio for the project would be 1.14 to 1. This is considerably inferior to the corresponding value of the benefit-cost ratio of 1.37 to 1 as derived from total costs of $27,762,000 and benefits of $38,160,000 for the Harden Project.

Groveland Project consists of the following proposed features:

- Mather Diversion
- Mather Ditch
- Harden Flat Diversion
- Golden Rock Ditch
- Burch Meadow Reservoir
- Groveland Reservoir
- Groveland Ditch
- Groveland Forebay
- Groveland Powerhouse

From Mather Diversion to Burch Meadow Reservoir, all of the features of the Groveland Project have their counterpart in the Harden Project. Mather Diversion Dam and Mather Ditch are designed to have the same alignment and capacity in both projects. Harden Flat Diversion of the Groveland Project would be a small diversion structure located at the site of Harden Flat Dam of the Harden Project. The Golden Rock ditch of the Groveland Project would follow approximately the same alignment as the Golden Rock ditch and Burch Meadow Conduit of the Harden Project. Since Harden Flat Diversion would provide little storage, Groveland Project's Golden Rock ditch is designed to a larger capacity (220 second-feet) than the corresponding conduit in the Harden Project. Lost Claim Forebay and Lost Claim Powerhouse would not be included in the Groveland Project. Burch Meadow Conduit of the Harden Project would become an extension of the Golden Rock ditch with a capacity of 220 second-feet in the Groveland Project. Burch Meadow Reservoir would be the same for either project.

The major storage reservoir of the Groveland Project is Groveland Reservoir. The 40,000 acre-foot reservoir would be formed by a modified homogeneous dam rising 210 feet from the streambed elevation of 2,440 feet on Big Creek in the northeast quarter of Section 15, Township 1 South, Range 16 East, MDB&M. The dam would have a crest length of 770 feet, a width of 30 feet, and slopes of $2\frac{1}{2}$:1 downstream and 4:1 upstream. The dam would contain 2,500,000 cubic yards of earth. The spillway would be an ungated chute with an ogee weir 200 feet in length constructed in the saddle to the left of the dam. At a normal pool elevation of 2,635 feet, the reservoir

would inundate one ranch headquarters and about 570 acres of privately owned cattle grazing land.

The Groveland ditch would extend in a northwesterly direction 5 miles from Groveland Reservoir to Groveland Forebay. The conduit, passing through an area of scattered brush and trees, would consist of 19,000 feet of open trapezoidal canal and 7,000 feet of semicircular flume. The design capacity of the conduit would be 170 second-feet.

Groveland Forebay would be formed by enlarging Groveland ditch to a bottom width of 50 feet and a depth of 15 feet for the last one-half mile. This results in approximately 55 acre-feet of storage which is sufficient to supply water in case of a sudden power demand until water could be supplied from Groveland Reservoir.

Groveland Powerhouse would consist of a single unit with an installed capacity of 16,100 kilowatts operating with a static head of 1,500 feet. The penstock supplying the plant would be 3,450 feet in length and would vary in diameter from 54 inches at the inlet to 42 inches at the powerplant.

CHAPTER VI. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The economy of Southern Tuolumne County has to some extent been retarded for want of water supplies. The basic objective of the Southern Tuolumne County investigation was to formulate plans for the development of water supplies for all beneficial uses considered, including irrigation, domestic, recreation, fish and wildlife, and production of hydroelectric power. A plan is presented for an economically justified project which could supply the domestic water requirements of Southern Tuolumne County and could develop the hydroelectric and recreation potential of the area. The inclusion of irrigation as a project purpose proved to be economically infeasible.

Summary

The area of the investigation is located in the southern portion of Tuolumne County on the west slope of the central Sierra Nevada. It ranges in elevation from about 300 feet in the foothill areas just above the San Joaquin Valley floor to about 13,000 feet at the crest of the Sierra Nevada. Of the 1,462,900 acres within Tuolumne County, about 172,620 acres are within the Southern Tuolumne area. The area is drained by a portion of the Tuolumne River system.

Precipitation and climate vary greatly within Southern Tuolumne County. Mean annual depth of precipitation varies from about 18 inches in the lowlands, to 35 inches in the Groveland area, and 55 inches at the crest of the Sierra Nevada. The lowlands

experience hot dry summers and mild winters. The central area of Southern Tuolumne County experiences moderate summers and cool winters. Above an elevation of about 5,000 feet, winters are long and usually severe; snowfall is heavy. Practically all precipitation occurs between October and April, inclusive.

The economy of Southern Tuolumne County is based primarily on recreation, agriculture, and lumbering. Also of importance is the production of hydroelectric power. These activities probably will continue into the future as the dominant features of the economy of the area, with recreation continuing to have the greatest potential for growth.

The principal area within Southern Tuolumne County which would benefit from development of the waters of the Tuolumne River consists of the potential urban, suburban, and recreation lands in the Groveland and upper Moccasin Units. Additional benefits would result from recreation developments constructed near project reservoirs.

Runoff from the Tuolumne River Basin is derived for the most part from melting snow. Peak streamflows, therefore, occur in the spring and early summer months. These flows vary greatly, not only within the year, but also from year to year.

Waters originating in the area have been developed extensively for use in the San Joaquin Valley and in the San Francisco Bay Area. During the late winter and spring in most years, flows are available which, if properly controlled and distributed, could

meet the year 2020 water requirements of Southern Tuolumne County for domestic and recreation uses.

Estimates of average annual consumptive use of applied water and average annual water requirements within the area in the year 2020 and at estimated maximum conditions of development are presented in Table 31. These estimates are based on the assumption that water will be available at a price within the ability of the user to pay.

Plans for conserving the waters of the Tuolumne River Basin represent part of a basin-wide master plan. Under the basin-wide plan, water would be developed for all beneficial purposes. Consideration was given first, however, to developments that would supply the consumptive water needs of Tuolumne County. Second, consideration was given to developing water for nonconsumptive purposes.

TABLE 31

ESTIMATED FUTURE AVERAGE ANNUAL CONSUMPTIVE USE OF APPLIED WATER AND AVERAGE ANNUAL WATER DELIVERY REQUIREMENTS WITHIN SOUTHERN TUOLUMNE COUNTY*

(In acre-feet per year)

Use	In year 2020		Estimated maximum needs	
	Consumptive use	Water delivery requirements	Consumptive use	Water delivery requirements
Irrigation	10,000	15,300	17,700	27,700
Domestic and recreation	1,400	2,500	1,400	2,500
TOTALS	11,400	17,800	19,100	30,200

* Assumes a water supply available at a cost within the ability of the users to pay.

Two alternative plans were considered for developing the waters of the Tuolumne River Basin for use within Southern Tuolumne County. These plans are the Harden and Groveland Projects. These projects, in addition to supplying water for consumptive use, would produce substantial amounts of hydroelectric energy and would increase the recreation potential of the area. A summary of the accomplishments of the Harden and Groveland projects is presented in Table 32. A summary of the benefits, costs, and benefit-cost ratios of the Harden and Groveland projects is presented in Table 33.

TABLE 32

ACCOMPLISHMENTS OF THE HARDEN PROJECT AND THE GROVELAND PROJECT

Project	Water supply acre-feet	Power		Recreation
		Capacity kilowatts	Energy, kilowatt hours per year	Visitor-days in 50-year period
Harden Project	1,800	22,000	90,700,00	26,200,00
Groveland Project	1,800	16,100	57,800,00	31,000,000

TABLE 33

BENEFITS, COSTS, AND BENEFIT-COST RATIOS FOR THE HARDEN PROJECT AND THE GROVELAND PROJECT

Item	Harden Project	Groveland Project
Total cost	$27,762,000	$31,700,000
Benefits		
Domestic water	700,000	700,000
Power	17,620,000	12,320,000
Recreation	19,840,000	23,137,000
TOTAL	$38,160,000	$36,157,000
Benefit-cost ratio	1.37	1.14

Conclusions

From analyses of data developed for the Southern Tuolumne County Investigation, the following conclusions have been reached.

1. The principal source of water for use within the area at present is from development of limited ground water resources.

2. Present water deliveries are about 400 acre-feet annually. Of this amount, about 60 percent is utilized for irrigation and 40 percent for domestic purposes.

3. Under conditions of development anticipated for year 2020, if water is made available at a cost within the users' ability to pay, it is estimated that the annual water delivery requirements within the area would be about 17,800 acre-feet. Under maximum conditions of development the estimated annual water delivery requirement within the area would amount to about 30,200 acre-feet.

4. The surface waters of the area are of excellent mineral quality suitable for all beneficial uses.

5. An estimated 11,090 net acres within the area are irrigable. Of this amount, about 70 acres presently are irrigated. An estimated 4,800 acres would be irrigated by the year 2020 if water can be made available at a cost within the users' ability to pay.

6. The estimated present average annual consumptive use of applied water within the area is 250 acre-feet. Of this

amount, about 90 acre-feet are used for domestic and recreation purposes and 160 acre-feet for agricultural purposes.

7. Estimated average annual consumptive use of applied water within the area in the year 2020 would be about 11,400 acre-feet, if water were made available at a cost within the users' ability to pay.

8. Conservation of surface runoff in major storage reservoirs is the most favorable long-term solution to providing substantial quantities of new water for use within the area. Water delivery requirements in the near future, however, could be met by possible increased use of ground water or by purchase of water from the Hetch Hetchy Aqueduct.

9. The Harden Project, one of two alternatives, involves major storage for supplying water to Southern Tuolumne County, and would provide about 1,800 acre-feet of water annually which, when combined with the water available from existing local developments, would meet the estimated requirements of the area for domestic uses in the year 2020. It would produce an average of about 91,000,000 kilowatt-hours of hydroelectric energy per year. It would help maintain streamflows of the Tuolumne River and would provide new recreation opportunities and facilities needed to accommodate 26,200,000 visitors over the 50-year repayment period. The Harden Project would have a benefit-cost ratio of about 1.37:1. The Harden Project does not include irrigation as a project purpose.

10. The Groveland Project, an alternative to the Harden Project, would provide about 1,800 acre-feet of water annually

which, when combined with the water available from existing local developments, would meet the estimated requirements of the area for domestic uses. It would produce an average of about 57,800,000 kilowatt-hours of hydroelectric energy per year. It would help maintain streamflows of the Tuolumne River and would provide new recreation opportunities and facilities to accommodate 31,900,000 visitors over the 50-year repayment period. The Groveland Project would have a benefit-cost ratio of about 1.14:1. The Groveland Project does not include irrigation as a project purpose.

11. The Groveland Project is sufficiently inferior to the Harden Project to justify its elimination from further consideration as a solution to the water supply problems of Southern Tuolumne County.

12. Both the Harden and Groveland Projects would deplete the flow of the Tuolumne River at Don Pedro Reservoir by about 2,400 acre-feet annually by the end of the 50-year project repayment period.

13. Studies indicate that the costs of distributing irrigation water would exceed the ability of the users to pay. Thus, irrigation was not included as a project purpose in either the Harden or Groveland Project.

Recommendations

It is recommended that:

1. This bulletin be used as a guide for future development of irrigation, domestic, and recreation water supplies from the Tuolumne River Basin; and further, that the plans presented in this bulletin be reviewed periodically and revised to meet the changing patterns of land and water use.

2. Public districts endowed with appropriate powers be created to proceed with more detailed studies to formulate a basin-wide plan for solution of local water problems, and provide for the recreation potentials of Southern Tuolumne County.

3. Such studies should include: (a) consideration of the Harden Project; (b) development of the tertiary gravel ground water basin as a single-purpose domestic water supply; and (c) determination of benefits that would accrue to the Harden Project, when financial assistance available to public agencies, as provided for by the Davis-Grunsky Act (Sections 12880-12891.1 inclusive of Chapter 5, Part 6, Division 6, of the Water Code), is considered.

4. If projects are found to be economically justified and financially feasible, the proposed districts proceed with the financing, construction, operation, and full development of these projects.

5. Southern Tuolumne County continue to make a concerted effort to partipate jointly with other water service agencies in furtherance of the development of the Tuolumne River Basin.

APPENDIX A

AGREEMENT

BETWEEN THE STATE OF CALIFORNIA, DEPARTMENT OF WATER RESOURCES, AND TUOLUMNE COUNTY

TABLE OF CONTENTS

Agreement No. 160022

COOPERATIVE AGREEMENT

BETWEEN THE STATE OF CALIFORNIA,
DEPARTMENT OF WATER RESOURCES,
AND TUOLUMNE COUNTY

This agreement, made and entered into as of the first day of July, 1958, by and between the State of California, acting by and through its Department of Water Resources, hereinafter referred to as the "State", and the County of Tuolumne, hereinafter referred to as the "County":

W I T N E S S E T H

WHEREAS, by Article 5, Chapter 1, Part 6, Division 6, of the Water Code of the State of California, the State is authorized to conduct investigations of the water resources of the State, formulate plans for the control, conservation, protection, and utilization of such water resources, including solutions for the water problems of each portion of the State as deemed expedient and economically feasible, and may render reports thereon; and

WHEREAS, by Article 4, Chapter 1, Part 6, Division 6, of the Water Code of the State of California, the State is authorized to cooperate with any county, city, state agency, or public district on flood control and other water problems and when requested by any thereof may enter into a cooperative agreement to expend money on behalf of any thereof to accomplish the purposes of Chapters 1 and 2 of this part; and

WHEREAS, the County has requested the State to make a cooperative investigation and report on a study by the State to determine the amount of water, if any, available for development and use in the southern part of the county.

NOW, THEREFORE, it is mutually agreed, subject to the availability of funds, as follows:

(1) The State shall perform the work provided for by this agreement and shall prepare the report and otherwise advise and assist in formulating solutions to the water problems of the area.

(2) The work program shall be set forth in the attachment marked "Exhibit A" and incorporated herein by reference.

(3) The County shall contribute $9,000 which shall be transmitted to the State prior to commencement of the work.

(4) The State shall contribute $9,000 from funds appropriated to the Department of Water Resources by the Budget Act of 1958.

(5) Funds contributed by the parties shall be deposited in the Water Resources Revolving Fund in the State Treasury for expenditure by the State in performance of the work provided for in this agreement.

(6) The State shall under no circumstances be obligated to expend for or on account of the work provided for under this agreement any amount in excess of the funds made available hereunder.

(7) A statement of expenditures for each fiscal year beginning July 1 and ending June 30, shall be furnished the

County by the State as soon as practicable after the close of the fiscal year.

(8) Upon completion and final payment for the work provided in this agreement, the State shall furnish to the County a statement of expenditures made under this agreement. Any unexpended balance of the total amount of the agreement shall be returned to the State and to the County in equal amounts.

IN WITNESS THEREOF, the parties hereto have executed this agreement.

Approved as to Form and Procedure

/s/ Scott K. Carter
Attorney, County of Tuolumne

COUNTY OF TUOLUMNE

By /s/ Carl K. Williams
Chairman, Board of Supervisors

Approved as to Form and Procedure

/s/ Mark C. Nosler
Chief Counsel, Department of Water Resources

State of California
Department of Water Resources

HARVEY O. BANKS
Director of Water Resources

By /s/ Paul L. Barnes
Paul L. Barnes, Chief
Division of Administration

Approved - Department of Finance

EXHIBIT A

EXTRACT FROM
PRELIMINARY REPORT
ON THE
WATER RESOURCES AND WATER PROBLEMS
IN SOUTHERN TUOLUMNE COUNTY

Proposed Work Program

The proposed investigation would cover a period of two years. The work of the first year would include the collection and analysis of basic data and the formulation of a plan for water development. Final evaluation of the plan, selection of a unit, or units for initial development, and the preparation and publication of a report of investigation would be accomplished during the second year.

The work program would include the following:

1. Hydrologic studies to estimate the available stream flow and availability of surplus water at proposed dam sites. These studies would include the most recent stream flow records and would consider existing projects and proposed projects by other agencies. From these studies, the new yield of water creditable to proposed projects under this investigation would be estimated, and its effect on existing development would be evaluated.

2. A land classification survey covering about 136,000 acres. These lands are located south of the Middle Fork and the main stream of the Tuolumne River. They extend from the Stanislaus County line on the west to Yosemite National Park on the east.

3. An economic study of the area, to include lands in the National Forest that have residential and recreational potential. The results of this study would indicate the size and type of development to be planned, and the ability of water users to repay the costs of water supply development.

4. Plans for enhancement of stream flows for fish and wildlife, and for recreational development. This would include planning and design of features devoted specifically to these purposes, as well as incorporating these features in projects designed primarily for water supply and hydroelectric power development.

5. Geologic investigations of dam sites and conduit routes. Core drilling would be conducted at sites chosen for subsequent detailed study. Mapping and testing of material suitable for construction purposes would be made.

6. Preparation of detailed maps and surveys to supplement existing surveys, as required, to properly evaluate project costs.

7. Hydroelectric studies to determine revenue-producing projects which could be integrated with irrigation projects.

8. Formulation of a plan of development for the area and determination of features, with possible alternatives, which could best serve the area as an initial project. The recommended initial project would be required to have engineering feasibility and economic justification. Further detail studies and design would be required to determine financial feasibility.

9. Completion of estimates of costs of all structures.

The report would contain the data and results of the investigation and, if found justifiable, it would include a proposed initial plan of water resources development for the area. It would include a description of works and a preliminary estimate of their costs and benefits.

Cost of Investigation

The cost of the investigation is estimated to be $18,000 for the first year and $18,000 for the second year, a total of $36,000 over the two-year period.

It is recommended that $36,000 be financed cooperatively, with the State and Tuolumne County each bearing one-half of the total cost. A portion of the cost of the investigation, appropriate to general Department of Water Resources activities, would be financed under the California Water Development Program.

The estimated cost to Tuolumne County would be $9,000 for the Fiscal Year 1958-59 and $9,000 for the Fiscal Year 1959-60, a total of $18,000 for the two-year period.

The cost to the State of California would be $9,000 for the Fiscal Year 1958-59, and $9,000 for the Fiscal Year 1959-60, a total of $18,000 for the two-year period.

ENDORSED
FILED

February 3 1958
James G. White, Clerk

NO. 41 19 57 58

By /s/ Carlo M. De Ferrari
Deputy Clerk

RESOLUTION

of the Board of Supervisors of the County of Tuolumne

WHEREAS, The Department of Water Resources of the State of California is proposing to make a study and investigation of the Water Resources and Water Problems in Tuolumne County, in cooperation with Tuolumne County Water District No. 2, as outlined in a preliminary report thereon dated December, 1957; and

WHEREAS, the proposed study will not include works for supplying water for the uses and requirements of that portion of Tuolumne County outside Tuolumne County Water District Nos. 1 and 2, unless such additional study is undertaken in cooperation with a local agency; and

WHEREAS, the County of Tuolumne may wish to contract for cooperation with the said State Department of Water Resources for such additional study, but the facts upon which to base a final determination of the desirability of such a contract are not yet available;

NOW THEREFORE, BE IT RESOLVED BY THE BOARD OF SUPERVISORS OF THE COUNTY OF TUOLUMNE, STATE OF CALIFORNIA, As follows:

Section 1. The Department of Water Resources is hereby respectfully requested to make a preliminary investigation and report on a study by said Department of the feasibility of constructing the storage and diversion works contemplated by the California Water Plan, or acceptable alternatives thereto, for services to the residents and lands within that portion of this county not included within Tuolumne County Water Districts Nos. 1 and 2; and to include in its said report of the preliminary investigation an outline of the scope of such proposed study, including a description of the particular activities to be undertaken; and to

estimate the cost thereof on the basis of cooperation in such an investigation by this County.

Section 2. The Clerk of this Board is hereby directed to send a certified copy of this resolution to the Director of the Department of Water Resources.

x

x

x

x

x

x

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x

THE FOREGOING RESOLUTION PASSED AND ADOPTED BY THE BOARD OF SUPERVISORS OF THE COUNTY OF TUOLUMNE, CALIFORNIA, ON THIS 3rd DAY OF February, 19 58

Ayes: Adelbert A. Hicholls
Supervisor 1st District
Frank J. Dondero
Supervisor 2nd District
Carl K. Williams
Supervisor 3rd District
Ralph P. Thiel
Supervisor 4th District
Clarence A. Kerr
Supervisor 5th District

Noes: None
Supervisor ____ District
Supervisor ____ District
Supervisor ____ District

Absent: None
Supervisor ____ District
Supervisor ____ District

Carl K. Williams
CHAIRMAN OF THE BOARD OF SUPERVISORS
COUNTY OF TUOLUMNE, STATE OF CALIFORNIA

ATTEST; JAMES G. WHITE, CLERK

By: Carlo M. De Ferrari
Deputy Clerk

SEAL

RESOLUTION NO. 41, 19 57, 58

I CERTIFY THAT THE FOREGOING IS A CORRECT COPY OF RESOLUTION NO. 41 ADOPTED BY TH BOARD OF SUPERVISORS OF TUOLUMNE COUNTY, CALIFORNIA, ON February 3, 19 58

DATED February 4, 19 58

James G. White, Clerk

By /s/ Carlo M. De Ferrari, Deputy

APPENDIX B

REGIONAL GEOLOGY

SOUTHERN TUOLUMNE COUNTY

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TABLE

PLATE

(Plate is bound at end of bulletin)

REGIONAL GEOLOGY

SOUTHERN TUOLUMNE COUNTY

Introduction

Evaluation of geologic factors is essential in the preparation of plans, designs, and cost estimates of engineering projects. Geologic factors which must be considered include topography, foundation conditions, and the location and types of native materials available for construction.

This appendix on the regional geology of the Southern Tuolumne County area has been prepared to provide geologic information which would aid in preparing surface water development plans in the area. The subject is discussed under the following headings: Geomorphology, Areal Geology, Seismicity, and Engineering Geology. More specific reports on the geology of project features have been prepared and are available in the files of the Department of Water Resources.

Previous Work and Acknowledgments

Most of the data presented on engineering geology are based on field investigations by Department of Water Resources personnel; the information presented on geomorphology, areal geology, and seismicity is based largely on data obtained from various published and unpublished geologic reports. A bibliography of published and unpublished reports utilized is presented at the end of this appendix.

Scope of the Investigation

Geologic studies in the Southern Tuolumne County area have included study of geologic formations with particular emphasis on the sites of proposed structures.

Possible units of water development projects in the Southern Tuolumne County area were treated in as much detail as finances and time allowed. These possible units are: the Mather diversion and conduit, Carl Inn Damsite, Groveland Damsite, and Groveland Conduit and Powerplant.

The objective of the geologic investigation of damsites and other hydraulic engineering structures in the Southern Tuolumne County area was to ascertain foundation conditions and availability of construction materials for the proposed structures. The geologic investigation included surface geologic mapping of dam and reservoir sites and conduit routes, preliminary foundation drilling, collection of soil samples to determine the properties of available materials, and determination of quantities of available materials. In studying the sites, emphasis was placed on the determination of rock types, degree of weathering, patterns of jointing, the nature and extent of shear zones and the engineering properties of foundation materials. The investigations varied from preliminary reconnaissance of surficial geologic features at some sites to subsurface exploration at other sites. The summary geology reports, which are available in the files of the Department of Water Resources, indicate the exploratory methods used at each site.

The areal geology of the Southern Tuolumne County area is shown on Plate B-1, "Regional Geology." The engineering properties of each lithologic unit are summarized in Table B-1.

Geomorphology

The Southern Tuolumne County area is situated on the gently westward dipping slope of the Sierra Nevada geomorphic province. This province is approximately 430 miles long and varies from 40 to 80 miles in width. The Sierra Nevada has been described as an immense, tilted fault block which ranges in elevation from near sea level along its western edge to a maximum height of 14,496 feet at Mount Whitney. In cross section the Sierra has a gentle westward slope averaging about 2^{o} and an abrupt eastern scarp. The eastern scarp owes its relief to the recency of the down faulting of the fault blocks to the east of the Sierra and the associated uplifting of the main Sierran block. Elevations in the Southern Tuolumne County area range from less than 300 feet near the western border to 6,037 feet on Crocker Ridge located to the east, near the western boundary of Yosemite Park.

The Sierra Nevada province is composed of a bedrock complex of intrusive igneous and metamorphic rocks which locally are unconformably overlain by Tertiary volcanic and sedimentary rocks. The geologic history of the area is long and complex.

The story of mountain building began late in Jurassic time, about 100 million years ago, when a great geosynclinal trough was compressed and initially uplifted. During this uplift great stresses were exerted upon the rocks and they became folded, broken, crushed, and metamorphosed. This period of stress and uplift was accompanied by a great amount of igneous activity deep within the earth. This igneous activity resulted in the formation of the Sierran batholith and the metamorphism of many older sediments. The batholith is composed of granitic rocks, principally granodiorite, quartz monzonite, quartz diorite, and true granite; but it also includes some basic intrusive igneous rocks such as gabbro. This period of igneous and metamorphic activity is believed to have ended by Late Cretaceous time. The ancestral Sierra Nevada had peaks which may have reached 6,000 or 7,000 feet in elevation. By the start of the Cenozoic era the mountains had been worn down, and the region as a whole had been reduced to a lowland. Renewed uplift of the mountain range began during the Eocene epoch. By Miocene time, the range had attained elevations of 5,000 to 6,000 feet and had developed a post mature topography. In general, the relief was fairly low. In mid-Miocene time, volcanic activity began along the Sierran crest. During the first stage of volcanism, rhyolite tuff and associated volcanic rocks were deposited over vast areas of the Sierra Nevada. This volcanism was associated with or was closely followed by additional uplift of the Sierra Nevada. One consequence of this latter uplift was a period of rapid erosion during which the streams became deeply incised

into the bedrock complex. During this period of erosion, much of the rhyolitic volcanic rock was stripped from the area. During a later stage of volcanism, which began in the middle Miocene Age and continued through mid-Pliocene time, huge quantities of andesitic and latitic volcanic debris poured out over the entire area. The volcanic materials choked many of the streams and forced them into new channels. These volcanic deposits may have attained a thickness of 5,000 feet or more. Faulting near the Sierran crest accompanied the volcanic activity and resulted in renewed uplift of the Sierra Nevada. This uplift was followed by a short period of relative quiescence during late Pliocene time. The close of the Tertiary period was marked by vigorous resumption of tectonic activity, and the range was further uplifted to its present elevation. During the Pleistocene epoch, snow and ice accumulated in the higher mountains and resulted in the formation of many slow moving glaciers. These glaciers greatly modified the topography by cutting huge U-shaped valleys (e. g. Yosemite Valley) and by depositing moraines. At the present time, several small glaciers still exist in the high mountain area east of Yosemite Valley.

Areal Geology

Two major subdivisions of the Sierra Nevada geomorphic province are present in the investigational area. These are: (1) a foothill subdivision largely underlain by metamorphic rocks. and (2) the High Sierra subdivision which is underlain principally by granitic rocks.

The foothill subdivision is confined to the western three-quarters of the area where metamorphic rocks form a

relatively broad northwest-trending belt of tight isoclinal folds. These folds locally were intruded by Mesozoic plutonic rocks which range from granite to peridotite in composition and are capped locally by mid- and late-Tertiary volcanic rocks. A northwest-trending foothill fault system cuts through the metamorphic rocks bringing Jurassic rocks and Paleozoic rocks into juxtaposition. The fault system varies in width from less than one mile to over three miles along its 120-mile length. Quartz veins and the Mother Lode mineral deposits are associated with this fault system.

The High Sierra subdivision includes the eastern quarter of the Southern Tuolumne area. It is underlain primarily by rocks of the granitic intrusive complex but also includes small areas of metamorphic rocks. Tertiary volcanic rocks and Pleistocene glacial debris locally blanket the bedrock complex.

Bedrock Series

The bedrock series consists of the Calaveras and Amador groups of metamorphic rocks and the granitic and basic intrusives which comprise the Sierra batholith.

Calaveras Group. The oldest rocks exposed in the investigational area have been assigned to the Calaveras group of Paleozoic age. This group includes many different rock types and is the most widespread metamorphic rock unit in the area. Moderately to intensely metamorphosed sedimentary rocks including phyllite, schist, chert, quartzite, marble, and tectonic breccia comprise the rocks of the Calaveras group. These rocks have been subjected to repeated folding and faulting; the resulting rock types and

structures are so complex that correlation within the group is often impossible. Some fossiliferous zones in the group have been so intensely altered that paleontologic age determination of the units is very difficult. Most authorities agree, however, that the rocks within the group are probably Paleozoic and possibly Carboniferous in age.

Amador Group. The Amador group consists of three formations which unconformably overlie the rocks of the Calaveras group. The oldest member of the Amador group is the Cosumnes formation of middle or late Jurassic age. It is overlain by the Logtown Ridge formation of Upper Jurassic age. The youngest formation of the group is the Upper Jurassic Mariposa formation. In general, the Amador group lies to the west of the Calaveras group and trends north-northwest along the Sierran foothills. The Amador group may approach 8,000 feet in thickness; however, the thickness varies considerably from place to place.

The Cosumnes formation has been recognized only recently in geologic literature and consequently has not been mapped extensively. Previously it had been included in both the Logtown Ridge formation and in the older Calaveras group. In the Southern Tuolumne County area the Cosumnes formation was not delimited as part of this investigation.

The Logtown Ridge formation consists of metamorphic rocks derived principally from flow and pyroclastic rocks of augite andesite and augite basalt composition. The rocks of this

formation are dark green, greenish gray, or gray and are classified as greenstones and green schist. Occasionally, small slate lenses are interbedded with the meta-volcanic rocks.

In the foothill belt of Southern Tuolumne County, most of the Mariposa formation consists of black to dark-gray slates. Minor amounts of quartzite and phyllite produced by the metamorphism of sandstone, conglomerate, and tuff are found interbedded with these slates.

Numerous fossils reportedly have been found in the rocks of the Amador group at various localities. These fossils definitely date the Amador group as ranging from middle to Upper Jurassic in age.

Granitic Rocks. Approximately the northeastern one-quarter of the investigational area is underlain by granitic rocks which are part of the Sierra Nevada batholith. The batholith is composed of a series of intrusions emplaced over a long period of time. This intrusive complex is composed of granite, quartz monzonite, granodiorite, quartz diorite, diorite, and other minor intrusive rocks.

In general, the most widespread of the intrusive rock types are coarse-grained granodiorite and porphyritic quartz monzonite. Quartz diorite and diorite also are widely distributed. The quartz monzonite appears to be one of the youngest of the granitic rocks which the granodiorite, quartz diorite, and diorite represent older intrusions. In the area investigated, the quartz monzonite is generally more resistant to erosion than are the other intrusives.

The Sierra Nevada batholith is believed to have been emplaced during Upper Jurassic to upper Cretaceous time. This age has been determined only recently by new laboratory methods and has placed the age of the batholith at about 90 million years.

Mafic and Ultramafic Intrusive Rocks. Gabbro, serpentine, and related rocks comprise the mafic and ultramafic intrusive rocks. These rocks are found most frequently in the foothill area associated with the foothill fault system. Small mafic intrusions also are found in the higher Sierra Nevada. These mafic and ultramafic intrusives are believed to be older than the more acidic, granitic intrusives, and thus are probably pre-Cretaceous in age.

Superjacent Series

Lithologic units in the superjacent series include: river gravels of Eocene (?) age; Sonora Pass formation (?) of Miocene age; and the Quaternary deposits.

River Gravels of Eocene (?) Age. The oldest Tertiary sediments in the Southern Tuolumne County area are weakly cemented sandstones and conglomerates which were deposited in ancient river channels. They are often referred to as auriferous gravels because they are occasionally gold-bearing. The remnants of these ancient channel deposits generally are confined to the region east and northeast of Groveland. The deposits consist of well rounded cobbles and gravels, and poorly indurated sandstones. The clastic materials were derived principally from metamorphic rocks and vein quartz.

The age of the ancient river gravels in the Southern Tuolumne area has not been established because no reliable index fossils have been found. These sediments are similar, however, to channel gravels in other areas which have been dated as Eocene.

The river gravels of Eocene (?) age are overlain by undifferentiated volcanic mudflows presumably of the Sonora Pass formation.

Material derived from the ancient river gravels was in part reworked by streams during the Pleistocene Age. During historic time, most of these deposits were again reworked by artificial means during man's quest for gold.

Sonora Pass Formation (?) The Sonora Pass (?) formation, as named by D. B. Slemmons, unconformably overlies the Tertiary gravels. This unit extends discontinuously from the Sierran crest westward toward the Great Valley of California. Portions of this formation previously have been mapped as the Mehrten formation; however, based on recent work it appears that the Mehrten formation does not extend into Tuolumne County. The formation varies in thickness from less than 100 feet in the foothills to more than 2,000 feet near the Sierran crest.

Members within the unit are essentially andesitic, but range from rhyolitic to basaltic in composition. The members include a variety of types of volcanic and clastic deposits. Near the Sierran summit, autobrecciated flows, mudflows, lava flows, and intrusions predominate over the associated gravels, sands, and clays. In the foothills adjacent to the Great Valley the converse is true.

Autobrecciated flows, mudflows, sands, and gravels predominate where the formation was observed. The mudflows consist of a variable amount of evenly distributed, angular, andesitic fragments in a fine-grained matrix of volcanic mud. The coarse fragments exceed 5 feet in diameter. The individual autobrecciated flows and/or mudflows range in thickness from a few feet to 50 or 60 feet. Locally these flows appear to be case-hardened. The case-hardening may affect only the outer 8 to 10 feet of the flow. Beneath this hard, cemented layer the material may be loose and crumbly. Locally, fluvial and lacustrine sediments are interbedded with the volcanics. These finer-grained deposits are generally confined to topographic lows which developed during the deposition of the Sonora Pass formation. The sedimentary rocks are moderately well indurated and occur in lenses ranging in thickness from less than 10 feet to several hundred feet. The sediments do not appear to be case-hardened.

The Sonora Pass formation locally is pervious and is Miocene in age. The age determination is based on fossil evidence from a number of localities in the Sierra Nevada and also on its relative stratigraphic position.

Quaternary Deposits. The Quaternary deposits include glacial debris, alluvium, colluvium, and lake deposits. Only the glacial debris and alluvium were mapped regionally because of the detail involved in delimiting the deposits. Where they locally

affect proposed structures, they were mapped in as much detail as time allowed.

The effects of glaciation are readily apparent throughout the High Sierra. U-shaped valleys, moraines, glacial erratics, hanging valleys, and many other features offer mute evidence of the great Pleistocene glaciers which once covered the area. Four separate ice advances have been noted: the Sherwin, Magee, Tahoe, and Tioga stages. In general, the Tahoe stage of glaciation was the most extensive of the four.

Glacial deposits in the area mapped are confined to ground, lateral, and terminal moraines. These are found both in valleys and on the mountain slopes, above 4,000 feet in elevation. The moraines are composed of unsorted, unstratified, poorly consolidated deposits termed till, which have been derived primarily from the granitic rocks.

Recent alluvium is confined to stream and river channel deposits and glacial basins. In general, such deposits have been stripped by glaciation from the higher mountain ranges. Rather extensive deposits of alluvium are found locally in the lower reaches of the Tuolumne River.

The alluvium consists of unconsolidated sand, gravel, and fines which locally are sorted. Alluvium which has been deposited in glacial basins, generally is highly organic.

The colluvium consists of gravitationally deposited debris which is unsorted and unconsolidated. It includes talus and slope-wash. The colluvium was not mapped on a regional scale.

Quaternary lake deposits are composed of sand, silt, and organic fines and occur only locally; they were not mapped regionally.

Seismicity

The area encompassed by the Southern Tuolumne area lies in a region of slight to moderate seismic activity. U. S. Coast and Geodetic Survey records list no earthquake shocks in the county in recorded times. However, several epicenters with Richter magnitudes of 4 to 5 have been recorded immediately east of the Tuolumne-Mono County line. In general, most of the seismic activity which affects Tuolumne County originates along the eastern scarp of the Sierra Nevada.

C. F. Richter, in "Seismic Regionalization," Bulletin of the Seismological Society of America, Vol. 49, No. 2, divides the State of California into several seismic regions. These regions are based on the expected maximum seismic intensity as measured on the Modified Mercalli Scale. Tuolumne County lies entirely within a region of a probable maximum of VI. However, it is significant that this figure (VI) assumed solid igneous and metamorphic bedrock. Locally, on deep alluvial fill the expected maximum seismic intensity would be IX.

The Modified Mercalli Scale of Intensity varies from I (weak) to XII (extreme). A brief summary of the effects that may be expected from shocks on this scale are presented on the following page.

I to V	Minor, very little damage to structures.
VI	Felt by all, many frightened. Trees and bushes shaken slightly. Liquids set in strong motion. Damage slight to poorly built buildings.
VII	Fright is general, all run outdoors. May be difficult to stand. Waves on ponds, lakes, and running water. Water turbid. Incaving of sand and gravel banks. Damage negligible to structures of good design and construction.
VIII	Fright general, alarm approaches panic. Noticed by persons driving automobiles. Trees shaken strongly. Changes in flow of wells and springs. Damage slight in specially designed structures, partial collapse in ordinary substantial buildings.
IX	Panic general, ground cracked conspicuously. Underground pipes broken. Serious damage to reservoirs and well-designed structures. Partial collapse of other structures.
X to XII	Serious to total damage to all structures. Lines of sight distorted. Earth slumps and landslides common.

Engineering Geology

The geologic units described herein display variations in engineering properties which depend upon the composition, texture, and geologic history of each unit. These properties are presented in Table B-1.

TABLE B-1

GENERALIZED DESCRIPTION OF ENGINEERING PROPERTIES OF LITHOLOGIC UNITS IN THE SOUTHERN TUOLUMNE AREA

Name and map symbol	Lithology	Weathering and soil development	Permeability		Workability	Cut slope stability
Alluvium Qal	Silty or clayey sand, sandy gravel, etc.; unconsolidated; locally grades into colluvium and glacial debris.	None to slight.	Highly variable.		Easily removed, easy to compact except where organic content is high.	Generally unstable in steep cuts, varies with clay content.
Glacial Debris Qm	Huge boulders and cobbles with some sand and associated fines; unsorted; unconsolidated.	Debris from older glacial epochs is deeply weathered; heavily forested.	Highly variable.		Generally common excavation; large boulders require blasting. Easily compacted.	Generally stable in low cuts.
Andesitic Volcanic Rocks Tv[a]	Volcanic mudflows and intervolcanic stream sediments.	Fresh where glaciated; deeply weathered at lower elevations.	Generally moderate to low. A few highly permeable lenses.	Unweathered	Requires light to moderate blasting.	Generally stable on steep slopes.
				Weathered	100% common.	Slopes stable at 1:1 to 1½:1; high slopes require berms.
Auriferous Gravels Tg	River gravels and sand, generally poorly cemented, crudely sorted. Deposits often reworked.	Often weathered, rarely has a soil cover.	Highly variable		Easily moved by power equipment.	Fair to good.
Granitic Rocks JKgrd and JKsy	Coarse- to fine-grained granitic intrusives ranging in composition from granite to diorite.	Generally fresh at higher elevation where glaciated; generally weathered at lower elevations; often has well developed soil profile.	None to slight where fresh. Highly variable where weathered.	Unweathered	Requires heavy blasting where slightly weathered or fresh.	Excellent; stable in vertical or nearly vertical cuts.

TABLE B-1 (Continued)

GENERALIZED DESCRIPTION OF ENGINEERING PROPERTIES OF LITHOLOGIC UNITS IN THE SOUTHERN TUOLUMNE AREA

Name and map symbol	Foundation conditions				Possible or reported use	Unit weight (pounds per cubic foot)	Unified soil classification group symbol
	Earth- or rockfill dam	Concrete dam	Canal	Tunnel			
Alluvium Qal	Generally suitable if organic content is low: not suitable beneath impervious section.	Not suitable.	Poor: probably would require special design and 100% lining.	Not suitable	Processed for concrete aggregate, pervious fill, road base material	80 to 135	Variable. SP, SW, SM, SC, CP, GW, GM, GC
Glacial Debris Qm	Same as alluvium.	Not suitable.	Generally poor, probably would require 100% lining.	Not suitable	Possible source of concrete aggregate pervious and impervious fill.	95 to 140	GP, GM, GC. SP, SM, SC
Andesitic Volcanic Rocks Tv[a] Unweathered	Poor; tends to slake; locally highly pervious.	Not suitable.	Fairly good; probably require 100% lining.	Poor; requires heavy support and 100% lining.	Possible source of rockfill.	110 to 165	
Andesitic Volcanic Rocks Tv[a] Weathered	Unsuitable, should be stripped.	Not suitable	Generally poor; requires lining.	Very poor; requires 100% lining and support.	None known.	80 to 120	GM, GC, SM, SC
Auriferous Gravels Tg	Not suitable.	Not suitable	Poor; requires lining.	Generally poor requires 100% lining and support.	Processed aggregate.	100 to 130	GP, GM, GC, SM, SC, SP
Granitic Rocks JKgrd and JKsy Unweathered	Excellent, requires only shaping.	Excellent; requires only shaping.	Good for flume; high cost of rock excavation precludes canal.	Very good, generally requires no support or lining.	Fresh rock used as rockfill and crushed aggregate.	155 to 170	

TABLE B-1 (Continued)

GENERALIZED DESCRIPTION OF ENGINEERING PROPERTIES OF LITHOLOGIC UNITS IN THE SOUTHERN TUOLUMNE AREA

Name and map symbol	Lithology	Weathering and soil development	Permeability		Workability	Cut slope stability
Granitic rocks Jh and rd and JKg	Coarse- to fine-grained granitic intrusives ranging in composition from granite to diorite.	Generally fresh at higher elevation where glaciated; generally weathered at lower elevations; often has well developed soil profile.	None to slight where fresh. Highly variable where weathered.	Weathered	Easily moved by power equipment where deeply weathered.	Stable at 1:1 to 1½:1.
Serpentine and other Ultrabasic Intrusive Rocks Jbi	Serpentine, peridotite, hornblendite, and associated mafic intrusive rocks.	Weathering slight except on joint surfaces; soil generally thin or absent.	Generally low; locally moderate.	Unweathered	Easily moved where sheared; requires blasting where massive.	Good where fresh; poor where sheared.
				Weathered	Easily moved where weathered.	Stable at 1¼:1 or 1½:1.
Amador Group Jl, Jm	Meta-sedimentary and meta-volcanic rocks; good cleavage, moderately hard to hard.	Intense to none; weathering is differential and unpredictable.	Highly variable.	Unweathered	Requires slight to heavy blasting.	Slopes affected by cleavage and joints. Variable ¼:1 to 1:1.
				Weathered	100% common.	Slopes stable at 1½:1 to 1½:1.
Calaveras Group Cc	Meta-sedimentary and meta-volcanic rocks; includes marble. Moderately hard to very hard.	Slight to none; weathering is differential and unpredictable.	None to high.	Unweathered	Requires slight to heavy blasting where fresh.	Slopes affected by cleavage and joints. Variable ¼:1 to 1:1.
				Weathered	100% common.	Slopes stable at about 1¼:1.

TABLE B-1 (Continued)

GENERALIZED DESCRIPTION OF ENGINEERING PROPERTIES OF LITHOLOGIC UNITS
IN THE SOUTHERN TUOLUMNE AREA

Name and map symbol		Foundation conditions				Possible or reported use	Unit weight (pounds per cubic foot)	Unified soil classification group symbol
		Earth- or rockfill dam	Concrete dam	Canal	Tunnel			
Granitic Rocks JK grd and JKsy	Weathered	Fair to very poor - often permeable, weak.	Unsuitable.	Generally good, may require lining.	Poor, often requires heavy support and lining.	Often used as impervious, semi-pervious or pervious (?) fill.	75 to 110	SM, SC, Cl
Serpentine and other Ultrabasic Intrusive Rocks Jbi	Unweathered	Not desirable; may require special design.	Generally not suitable.	Fair to good; may require extensive lining.	Fair to very poor; often requires 100% support and lining.	Serpentine occasionally used as fill.	150 to 185	
	Weathered	Not suitable.	Not suitable.	Fair to poor; require 100% lining.	Very poor, requires 100% lining and heavy support.	None known.	90 to 110	SM, CL, SC, ML
Amador Group Jl, Jm	Unweathered	Very good.	Fair to good.	Good for canal; high rock excavation costs preclude canal.	Good to fair; some support and lining may be required.	Massive units occassionally quarried for rockfill.	150 to 170	
	Weathered	Fair, may require deep cutoff.	Unsuitable.	Good, should be lined.	Poor, generally requires much support and lining.	None known.	80 to 110	ML, SM, SC,
Calaveras Group Cc	Unweathered	Good.	Fair to good.	Good for flume; high excavation costs preclude canal.	Good to fair, may require some support and lining.	Massive units occassionally quarried for rockfill.	150 to 170	
	Weathered	Fair, not suitable beneath impervious section	Unsuitable.	Good, may require some lining.	Poor, requires heavy support and lining.	Possibly useful as impervious fill.	80 to 110	ML, CM

Bibliography

1. Bowen, O. E., Jr., and Crippen, R. A., Jr., "Geologic Maps and Notes along Highway 29," California Division Mines Bulletin 141, pp. 35-96. Maps 1-10, 1:125,000, 1948.

2. Clark, L. D., "Foothills Fault System, Western Sierra Nevada, California," Geol. Sci. of Am., Vol. 71, pp. 489-496, 1960.

3. Curtis, G. H., "Mode of Origin of Pyroclastic Debris in the Mehrten Formation of the Sierra Nevada," University of California Publication in Geological Sciences, Vol. 29, No. 9, pp. 453-502, Plates 35-45, 1954.

4. Fairbanks, H. W., "Geology of the Mother Lode Region," California Min. Bur. 10th Ann. Rept., pp. 23-90. Map p. 23, 1:62,500, 1910.

5. Heyl, G. R., "Foothill Copper-Zinc Belt of the Sierra Nevada, California," California Div. Mines Bull. 144, pp. 11-30. Pl. 1, 1:1,500,000, 1948.

6. Knopf, A., "The Mother Lode System of California," U. S. Geol. Survey Prof. Paper 157, 88 p. Pl. 2, 1:63,360; Pl. 9, 1:8,000, 1929.

7. Lindgren, W., "The Tertiary Gravels of the Sierra Nevada of California," U. S. Geol. Survey Prof. Paper 73, 226 pp. Pl. 1, 1:750,000, 1911.

8. Logan, C. A., "Mother Lode Gold Belt of California," California Div. Mines Bull. 108, 240 pp. Pls. 2, 3, 6, 8 and 10, 1:62,500, 1934.

9. Piper, A. M., and others, "Geology and Groundwater Hydrology of the Mokelumne Area, California," U. S. Geol. Survey Water-Supply Paper 780, 230 pp. Pl. 1, 1:62,360; Pls. 4 and 5, 1:500,000, 1939.

10. Ransome, F. L., "Some Lava Flows of the Western Slope of the Sierra Nevada, California," U. S. Geol. Survey Bull. 89, 74 p. Pl. 2, 1:125,000, (latites and associated volcanic rocks), 1898.

11. Ransome, F. L., "Description of the Mother Lode District," U. S. Geol. Survey Geol. Folio 63, 11 pp. Map, 1:63,360, 1900.

12. Turner, H. W., "Description of the Gold Belt; Description of the Jackson Sheet," U. S. Geol. Survey Geol. Folio 11, 6 pp. Map, 1:125,000, 1894.

13. Turner, H. W., "The Rocks of the Sierra Nevada," U. S. Geol. Survey Ann. Rept. 14, Pt. 2, pp. 435-495, Pl. 49, 1:62,500; Pl. 58, 1:62,500.

14. Turner, H. W., and Ransome, F. L., "Description of the Gold Belt; Description of the Big Trees Quadrangle," U. S. Geol. Survey Geol. Folio 51, 8 pp., Map, 1:125,000, 1898.

APPENDIX C

AGREEMENT BETWEEN THE COUNTY OF TUOLUMNE, TUOLUMNE COUNTY WATER DISTRICT NO. 2

AND

TURLOCK, MODESTO, AND WATERFORD IRRIGATION DISTRICTS AND THE CITY AND COUNTY OF SAN FRANCISCO

A G R E E M E N T

Agreement between Tuolumne County Water District No. 2, the County of Tuolumne (hereinafter both may be referred to as Tuolumne County Interests), and Turlock Irrigation District, Modesto Irrigation District, Waterford Irrigation District and the City and County of San Francisco (hereinafter collectively may be referred to as Downstream Interests) re use of water in the Upper Tuolumne River Watershed.

WHEREAS, Tuolumne County Water District No. 2 has pending before the State Water Rights Board Applications No. 12257, 12493, 12498, 12856, 13827, 13875 and 19423, and the County of Tuolumne has pending before the State Water Rights Board Applications No. 12871, 13011 and 13012, all involving proposed appropriation of water from the Upper Tuolumne River Watershed, and

WHEREAS, the State Water Rights Board, in letters dated July 30, 1963 and August 15, 1963 to applicants and protestants, indicates that it contemplates setting all of the heretofore enumerated applications of the Tuolumne County Interests for hearing in the near future and has scheduled hearings thereon for December 10, 1963; and

WHEREAS, the Downstream Interests have protested a number of the applications enumerated herein on the basis, among other things, that the diversions by the Tuolumne County Interests as proposed thereunder would interfere with Downstream Interests prior rights for diversion and use of water from the same Watershed; and

WHEREAS, Tuolumne County Water District No. 2 has indicated that the only project on which it is now in a position to proceed with construction is the Tuolumne River Project as set forth under applications 12493 and 19423 as now amended and that it has no immediate plans to proceed with the developments proposed under the other applications; and

WHEREAS, the County of Tuolumne has indicated that it has no immediate plans to proceed with the developments proposed under its applications except that the County envisions a project in the future similar to that described under application 12493 and 19423 of the Tuolumne County Water District No. 2; and

WHEREAS, the Tuolumne County Interests and the Downstream Interests desire to cooperate in providing for the full development of the Tuolumne River Watershed insofar as possible and to that end desire to enter into an agreement which will allow upstream development to take place on a limited basis and at the same time prevent undue interference with the prior rights of Downstream Interests;

NOW, THEREFORE, BE IT AGREED AS FOLLOWS:

1. Tuolumne County Water District No. 2 will forthwith advise the State Water Rights Board that the District intends only to proceed to hearing on water rights applications 12493 and 19423 as now amended on file with the State Water Rights Board, and that it will forthwith cause the deletion of all reference to the appropriation of water from the Tuolumne River Watershed in water right applications 12257 and 12498 and that it will withdraw, without prejudice, applications 12856, 13827 and 13875;

2. Tuolumne County Water District No. 2 agrees to operate its proposed Tuolumne River project, as set forth in the Goodenough, Sudman and Overholser, Inc. report dated December 1962 and described in water right applications 12493 and 19423, under the operating criteria appended to this agreement entitled "Operating Criteria - Tuolumne River Project";

3. Tuolumne County will withdraw its applications 12871, 13011 and 13012 now pending before the State Water Rights Board, without prejudice to the filing of new applications for domestic, municipal, recreational, and fish and wildlife purposes, at such time as the County is able to develop a specific project for these purposes;

4. Downstream Interests agree not to oppose future water right applications of the County of Tuolumne for any project for domestic and municipal uses and essentially non-consumptive recreational, fish and wildlife uses, all such uses being within the boundaries of Tuolumne County, similar to that proposed under water rights applications 12493 and 19423 of the Tuolumne County Water District No. 2, provided such project is supported by a showing of feasibility and provided it is subject to similar operating criteria to be agreed upon with Downstream Interests as set forth in the attachment to this agreement entitled "Operating Criteria - Tuolumne River Project";

5. Downstream Interests will withdraw any objections to water right applications 12493 and 19423 of Tuolumne County Water District No. 2, as now amended, now pending before the State Water Rights Board, and will not appear in opposition to said applications;

6. Nothing contained herein or in the operating criteria appended to this agreement shall affect the right of Waterford Irrigation District to receive its share of the full natural flow of the Tuolumne River at La Grange as such share would naturally occur under its prior vested water rights.

7. Nothing contained in this agreement shall prejudice the rights of Tuolumne County Interests to propose and prosecute new projects to which Downstream Interests do not consent, to the same extent as if this agreement had not been entered into.

8. All parties signatory hereto agree to submit this agreement to the State Water Rights Board, authorizing that Board to take such action as is necessary to carry out the terms hereof and requesting the Board to insert conditions in any permits issued on applications 12493 and 19423 subjecting diversion and use of water under said permits to the provisions of this agreement and the operating criteria appended hereto.

Dated this 2nd day of December, 1963.

TURLOCK IRRIGATION DISTRICT

By: /s/ A. M. Crowell
President

By: /s/ R. S. Tillner
Secretary

MODESTO IRRIGATION DISTRICT

By: /s/ R. E. Penney
President

By: /s/ H. L. Brooks
Secretary

WATERFORD IRRIGATION DISTRICT

By: /s/ Isaac F. Bashor
President

By: /s/ Cecil A. Hensley
Secretary

CITY AND COUNTY OF
SAN FRANCISCO
(Public Utilities Commission)

By: _____

By: /s/ Robert C. Kirkwood
Manager of Utilities

COUNTY OF TUOLUMNE

By: /s/ Robert W. Ingalls
Chairman, Board of Supervisors
James G. White, Clerk

By: /s/ Carlo M. DeFerran
Deputy

TUOLUMNE COUNTY WATER
DISTRICT NO. 2

By: /s/ Herbert E. Wilson
President

By: /s/ Harry S. Hinkley
Secretary

AUTHORIZED BY RESOLUTION NO. 23,500
Adopted December 17, 1963

By: /s/ James J. Finn
Secretary, Public Utilities Commission
City and County of San Francisco

APPROVED AS TO FORM:

WILLIAM F. BOURNE
Public Utilities Counsel

By: /s/ McMorris M. Dow
Deputy City Attorney

OPERATING CRITERIA - TUOLUMNE RIVER PROJECT

I. The Tuolumne River Project is that project described under applications 12493 and 19423 of the Tuolumne County Water District No. 2 as are now pending before the State Water Rights Board and as also described in the Goodenough, Sudman and Overholzer. Inc. report dated December 1962.

II. (a) For the purpose of operation only, the Tuolumne County Water District No. 2 project is deemed not to cause major interference with the downstream prior use by the Turlock, Modesto, and Waterford Irrigation Districts in years in which from April 1 to July 31 estimated full natural flow of the Tuolumne River at La Grange is in excess of 1,000,000 acre-feet, and accordingly the provision of paragraph IV of these criteria will not apply in such years.

(b) For purposes of determining operation under these criteria the full natural flow of the Tuolumne River at La Grange, as estimated by the California Cooperative Snow Surveys of the State Department of Water Resources as of April first of each year, shall be used.

III. When the April 1-July 31 estimated full natural flow of the Tuolumne River at La Grange is in excess of 1,000,000 acre-feet there shall be no decrease in discharge over inflow (hereinafter referred to as depletions) to the Tuolumne River during this period by Tuolumne County Water District No. 2 at any time when the computed full natural flow of the river at this point drops below 2516 cubic feet per second.

IV. In years when the April 1-July 31 estimated full natural flow of the Tuolumne River at La Grange is less than 1,000,000 acre-feet the following criteria shall govern the operation of the Tuolumne River project:

A. Tuolumne County Water District No. 2 may receive credit for increases in discharge over inflow (hereinafter described as accretions) to the Tuolumne River as a result of the construction and operation of its project, provided:

1) The amount of accretion credit to be received during the period October 1 through December 31 of any year shall not exceed the difference between the maximum storage permitted in Don Pedro Reservoir under flood criteria as of January 1 of each year (90,000 acre-feet in the case of existing Don Pedro or such other amount as is established for New Don Pedro) and the amount of water in storage in said reservoir on January 1 without the accretions.

2) In the event of a necessity for evacuation of storage from existing or New Don Pedro Reservoir during the flood control season as a result of storm conditions, all accretion credits and depletion debits previously attributed to Tuolumne County Water District No. 2 shall be cancelled.

B. The total sum of the depletion debits created by the Tuolumne River Project by Tuolumne County Water District No. 2 for the period October 1 of each year to September 30 of

succeeding year, shall not exceed the accretion credits for this same period, provided that Tuolumne County Water District No. 2 will not be charged with depletions at any time that the Downstream Interests are releasing water below La Grange which is not legally required. Any such depletion not charged will not exceed the accretions made during the previous accretion period. If necessary, releases from storage shall be made by Tuolumne County Water District No. 2 to accomplish this result.

C. Sufficient releases from storage from the Tuolumne River Project shall be made by Tuolumne County Water District No. 2 in advance of September 1 of each year at rates not to exceed 200 cubic feet per second so that, with normal releases only during September, by September 30 of each year the depletions for the previous twelve-month period shall not exceed the accretions.

V. Water used by Tuolumne County Water District No. 2 from the Tuolumne River Project for domestic and municipal purposes shall not exceed 5,000 acre-feet per annum without further agreement with Downstream Interests. Such water will not be served by Tuolumne County Water District No. 2 to areas outside of the boundaries of Tuolumne County.

VI. Tuolumne County Water District No. 2 shall make information available as follows to the Downstream Interests with respect to the operation of its Project:

A. Reservoir stage of Pine Valley and Bell Meadows Reservoirs on a monthly basis; stage of Browns Meadow Reservoir on a daily basis.

B. Daily releases from Pine Valley, Bell Meadows and Browns Meadow Reservoirs.

C. Daily Diversions from the Project by the District for domestic and municipal uses.

The above information is to be supplied by Tuolumne County Water District No. 2 at no cost to Downstream Interests and may be modified from time to time so long as it meets with the approval of both parties.

APPENDIX D

CLAIMED WATER RIGHTS
OF
TURLOCK, MODESTO, AND WATERFORD
IRRIGATION DISTRICTS

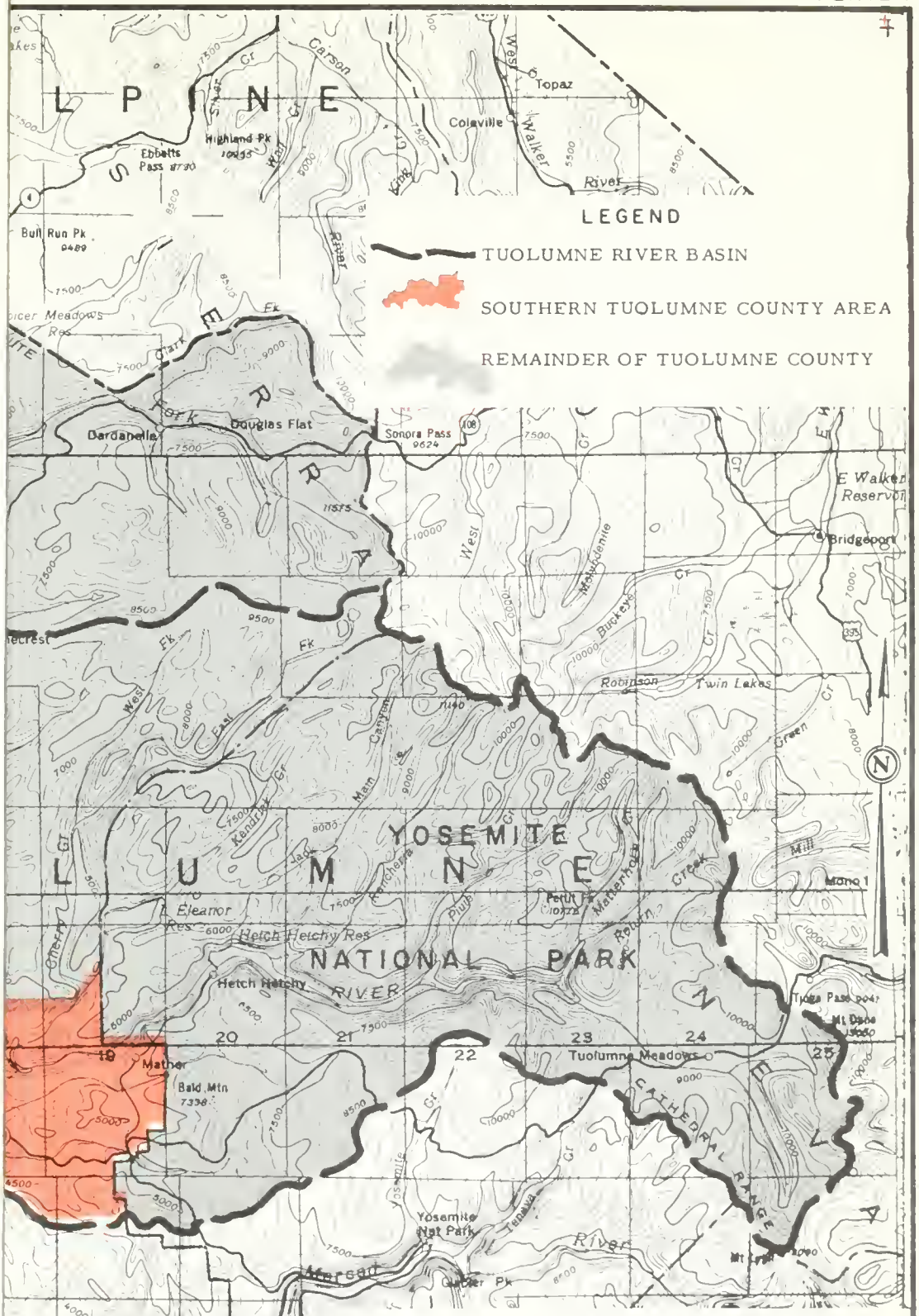
ESTABLISHED PRIOR TO DECEMBER 1914

WATER RIGHTS OF TURLOCK, MODESTO, AND WATERFORD
IRRIGATION DISTRICTS ESTABLISHED PRIOR TO DECEMBER 1914
(As submitted by Turlock and Modesto Irrigation Districts)

	Date of Posting	By	Present Power	Amount Diversion	Amount Storage Ac. Ft.	Location
1.	May 18, 1871	F. Green A. D. Allen	Waterford Turlock and Modesto La Grante	66 cfs		Originally between Red Mountain Bar and Jacksonville. Now La Grange Dam
2.	January 16, 1855	Franklin Water Co.	Turlock and Modesto			La Grange Dam
3.	January 18, 1862	Elam Dye	Turlock and Modesto			La Grange Dam
4.	May 18, 1872	John Burcham M. A. Wheaton Charles Elliot	Turlock and Modesto	500,000 M.I.		La Grange Dam
5.	January 5, 1889	Turlock	Turlock and Modesto	225,000 M.I.		La Grange Dam
6.	June 21, 1890	Modesto	Turlock and Modesto	250,000 M.I.		La Grange Dam
7.	October 1, 1908	Modesto	Modesto (Storage) Turlock and Modesto (Diversion)	50,000 M.I.	40,000	La Grange Dam
8.	August 31, 1911	Turlock	Turlock (Storage) Turlock and Modesto (Diversion)	200,000 M.I.	100,000	La Grange Dam
9.	February 27, 1913	J. M. Finley	Waterford	13,000 M.I.		La Grange Dam
10.	November 13, 1913	Waterford	Waterford	16,000 M.I.		La Grange Dam

Modesto, Turlock, and Waterford refer to the respective Irrigation Districts
The sum of 1, 9, and 10 does not exceed 250 cfs to Waterford
The sum of 2, 3, 4, 5, 6, 7, and 8 does not exceed 4500 cfs diversion to Turlock and Modesto

PLATE I



STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN VALLEY BRANCH
SOUTHERN TUOLUMNE COUNTY INVESTIGATION

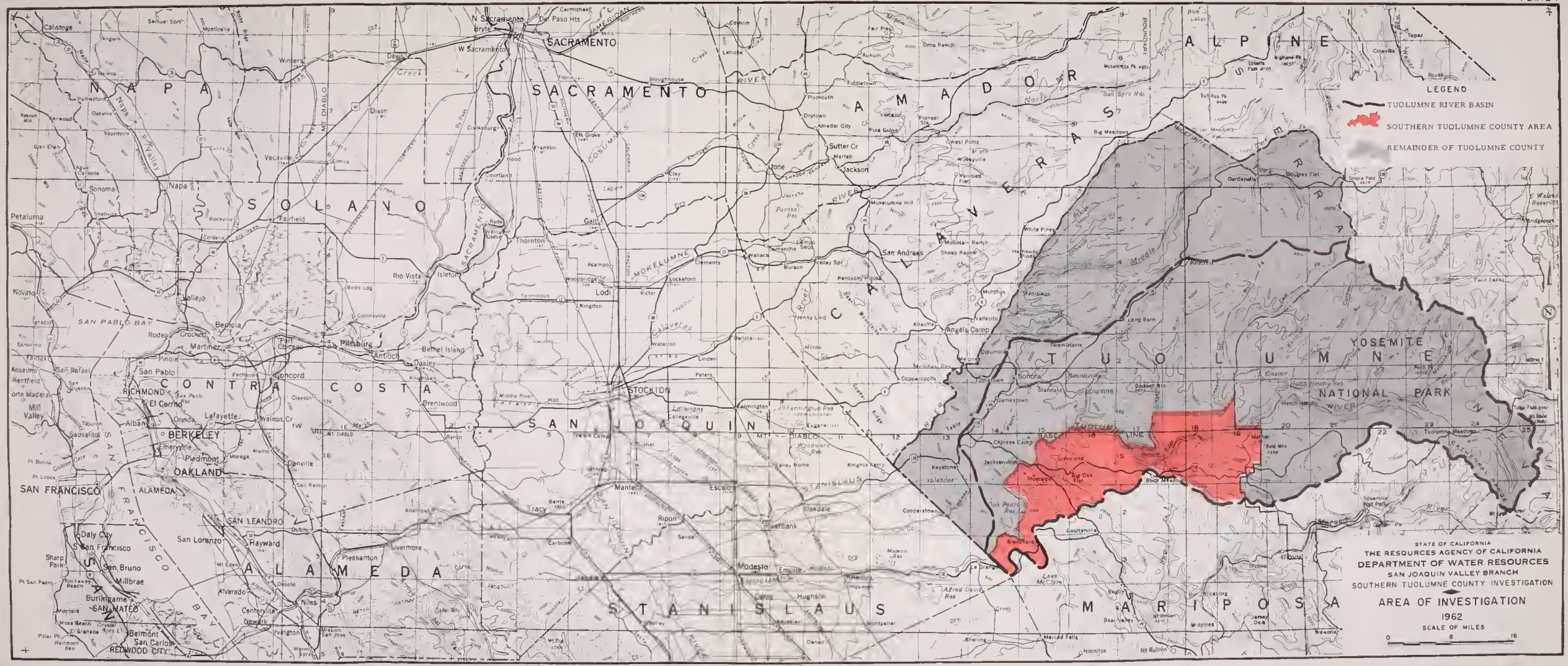
AREA OF INVESTIGATION

1962

SCALE OF MILES

0 8 16

PLATE I


LEGEND
TUOLUMNE RIVER BASIN
SOUTHERN TUOLUMNE COUNTY AREA
REMAINDER OF TUOLUMNE COUNTY
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN VALLEY BRANCH
SOUTHERN TUOLUMNE COUNTY INVESTIGATION
AREA OF INVESTIGATION
1962
SCALE OF MILES
0 8 16
SACRAMENTO
NAPA
SOLANO
CONTRA COSTA
ALAMEDA
SAN JOAQUIN
STANISLAUS
AMADOR
CALAVERAS
TUOLUMNE
MARIPOSA
ALPINE
YOSEMITE NATIONAL PARK
SACRAMENTO RIVER
SAN JOAQUIN RIVER
MOKELUMNE RIVER
STOCKTON
SAN FRANCISCO
OAKLAND
BERKELEY
RICHMOND
SAN LEANDRO
HAYWARD
MT DIABLO BASE LINE
SAN PABLO BAY
SUISUN BAY
SAN FRANCISCO BAY

INDEX TO PRECIPITATION STATIONS SNOW COURSES AND STREAM GAGING STATIONS

MAP REF NO	STATION
	PRECIPITATION STATIONS
1	LA GRANGE
2	DON PEDRO RESERVOIR
3	JACKSONVILLE
4	MOCCASIN
[illegible]	PRIEST
6	GROVELAND
7	GROVELAND RANGER STATION
8	EARLY INTAKE POWER HOUSE
9	LAKE ELEANOR
10	HETCH HETCHY
11	MATHER
[illegible]	[illegible]ROCKER STATION
	SNOW COURSES
13	LOWER KIBBIE RIDGE
14	VERNON LAKE
15	BEEHIVE MEADOW
16	[illegible] FLAT
	STREAM GAGING STATIONS
[illegible]	FALLS CREEK NEAR HETCH HETCHY
18	TUOLUMNE RIVER AT HETCH HETCHY [illegible] (INUNDATED)
19	TUOLUMNE RIVER AT HETCH HETCHY DAM SITE
[illegible]	TUOLUMNE RIVER NEAR HETCH HETCHY
21	TUOLUMNE RIVER MIDDLE FORK NEAR MATHER
[illegible]	CHERRY CREEK NEAR HETCH HETCHY (INUNDATED)
[illegible]	ELEANOR CREEK NEAR HETCH HETCHY
24	CHERRY CREEK BELOW CHERRY VALLEY DAM NEAR HETCH HETCHY
[illegible]	TUOLUMNE RIVER SOUTH FORK AT [illegible] FLAT
26	TUOLUMNE RIVER SOUTH FORK NEAR SEQUOIA
27	CHERRY CREEK NEAR EARLY INTAKE
28	CHERRY CREEK CANAL NEAR EARLY INTAKE
29	TUOLUMNE RIVER ABOVE EARLY INTAKE
30	SAN FRANCISCO TUNNEL DIVERSION NEAR HETCH HETCHY
	GOLDEN ROCK DITCH NEAR SEQUOIA
32	JAWBONE CREEK NEAR TUOLUMNE
33	CORRAL CREEK NEAR GROVELAND
34	TUOLUMNE RIVER MIDDLE FORK AT OAKLAND RECREATION CAMP
35	TUOLUMNE RIVER SOUTH FORK NEAR OAKLAND RECREATION CAMP
36	TUOLUMNE RIVER SOUTH FORK NEAR BUCK MEADOWS
37	TUOLUMNE RIVER, NEAR BUCK MEADOWS
38	CLAVEY RIVER NEAR TUOLUMNE
39	[illegible] RIVER NEAR BUCK MEADOW
40	INDIAN CREEK NEAR TUOLUMNE
41	BIG CREEK NEAR GROVELAND
42	MOCCASIN POWER PLANT DISCHARGE NEAR HETCH HETCHY
43	TUOLUMNE RIVER, NEAR JACKSONVILLE
44	WOODS CREEK NEAR JACKSONVILLE
45	TUOLUMNE RIVER ABOVE LA GRANGE DAM
46	TUOLUMNE RIVER NEAR LA GRANGE
47	SIERRA AND SAN FRANCISCO POWER COMPANY CANAL NEAR LA GRANGE
48	TURLOCK CANAL NEAR LA GRANGE
49	MODESTO CANAL NEAR LA GRANGE
[illegible]	TUOLUMNE RIVER AT LA GRANGE BRIDGE
	POINTS OF ESTIMATED RUNOFF
[illegible]	[illegible] CREEK AT BURCH MEADOWS
[illegible]	TUOLUMNE RIVER SOUTH FORK AT HARDEN FLAT
[illegible]	TUOLUMNE RIVER MIDDLE FORK AT MATHER DIVERSION

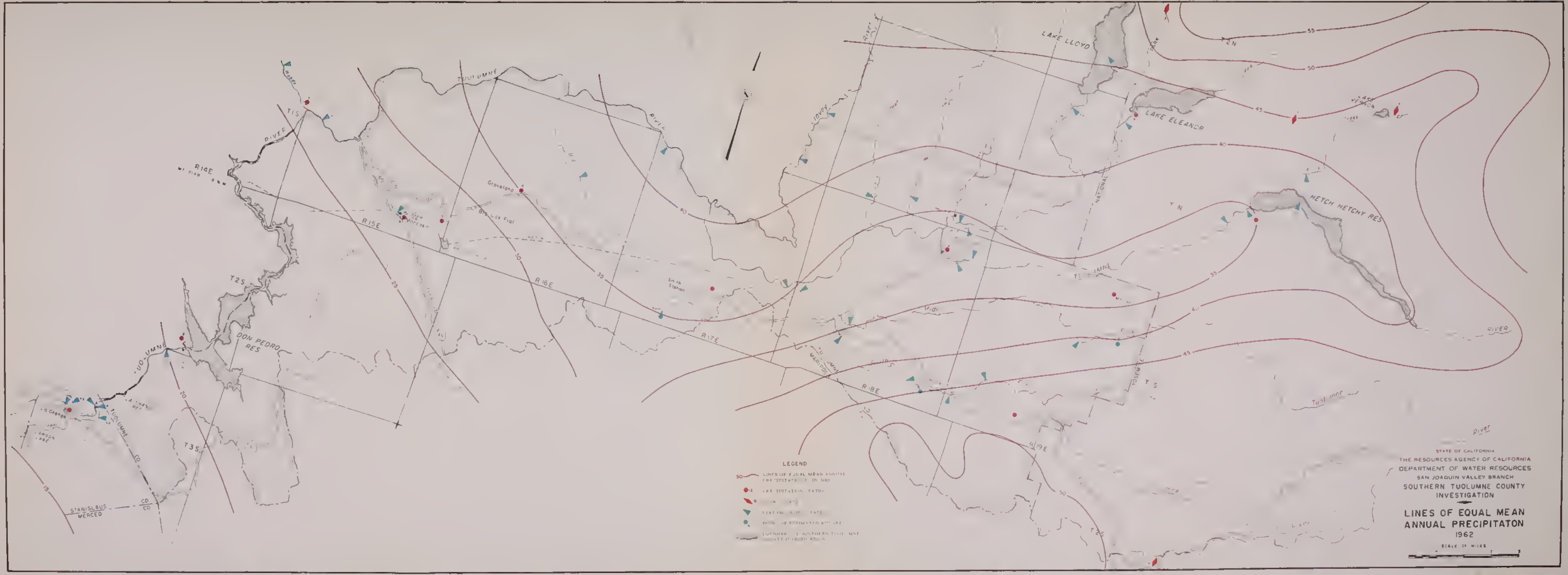
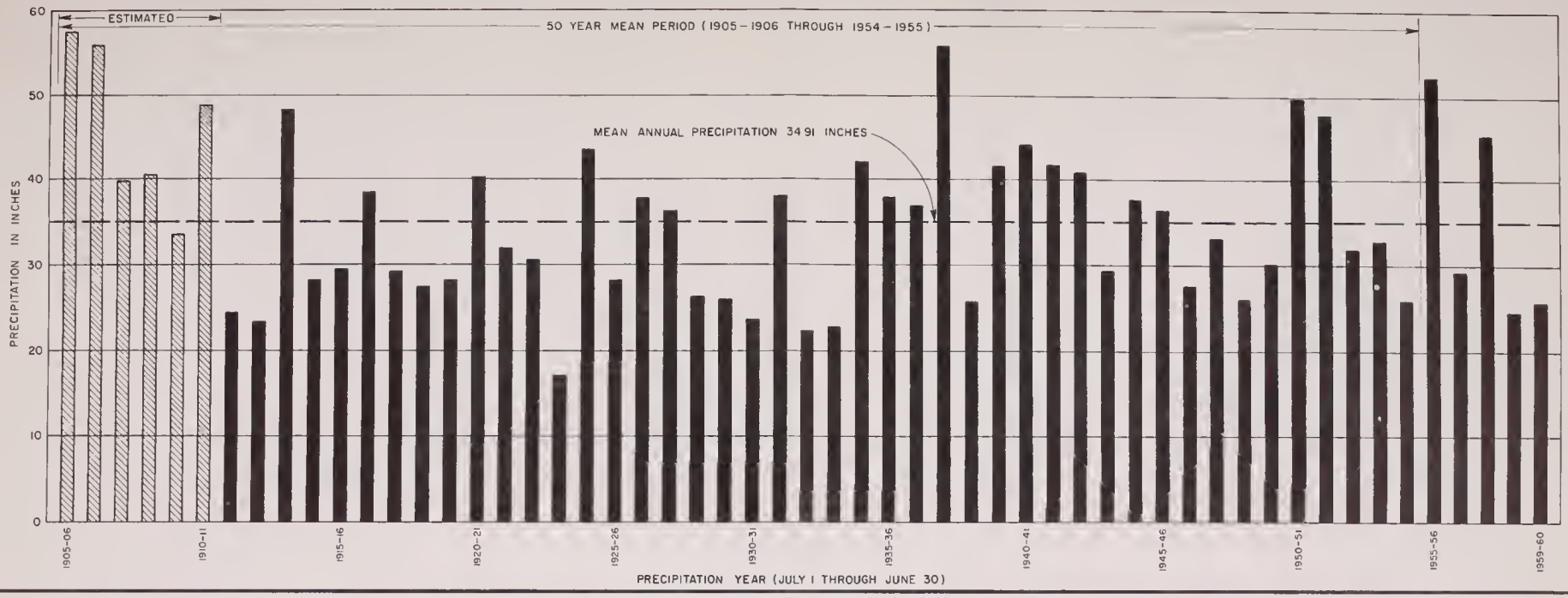
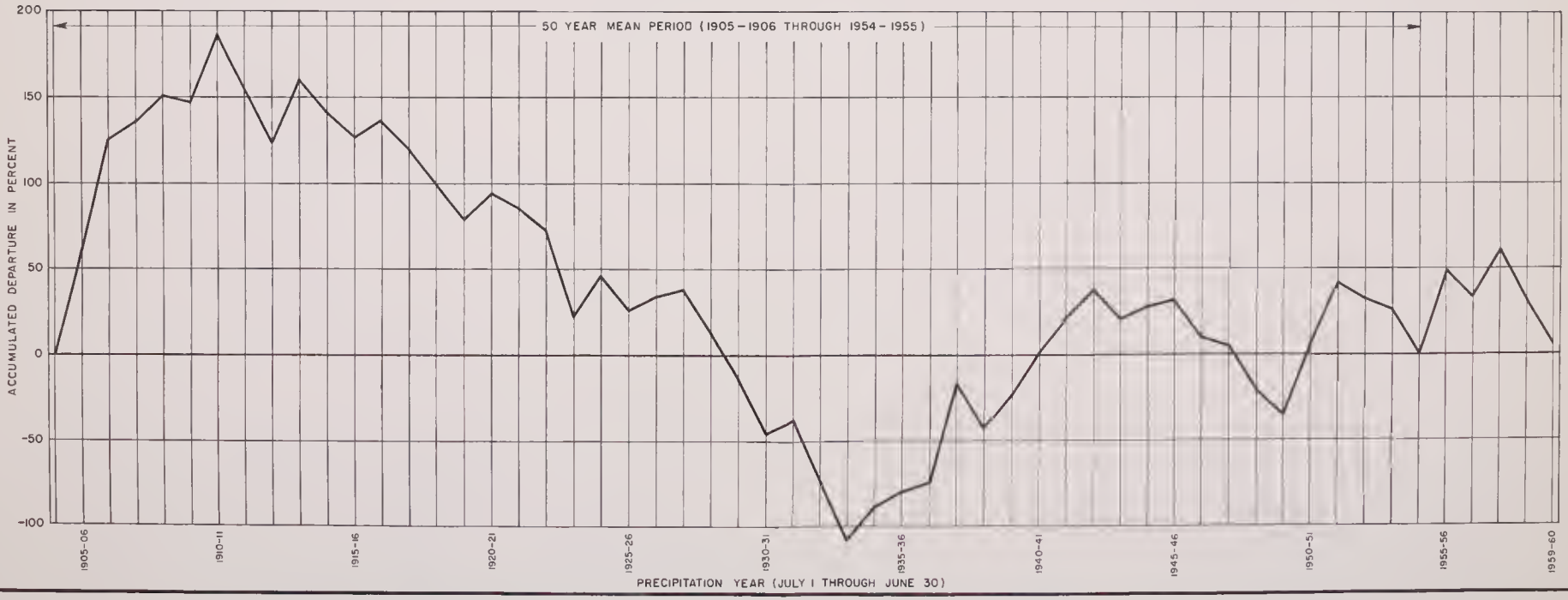


PLATE 3-A



RECORDED AND ESTIMATED ANNUAL PRECIPITATION AT HETCH HETCHY

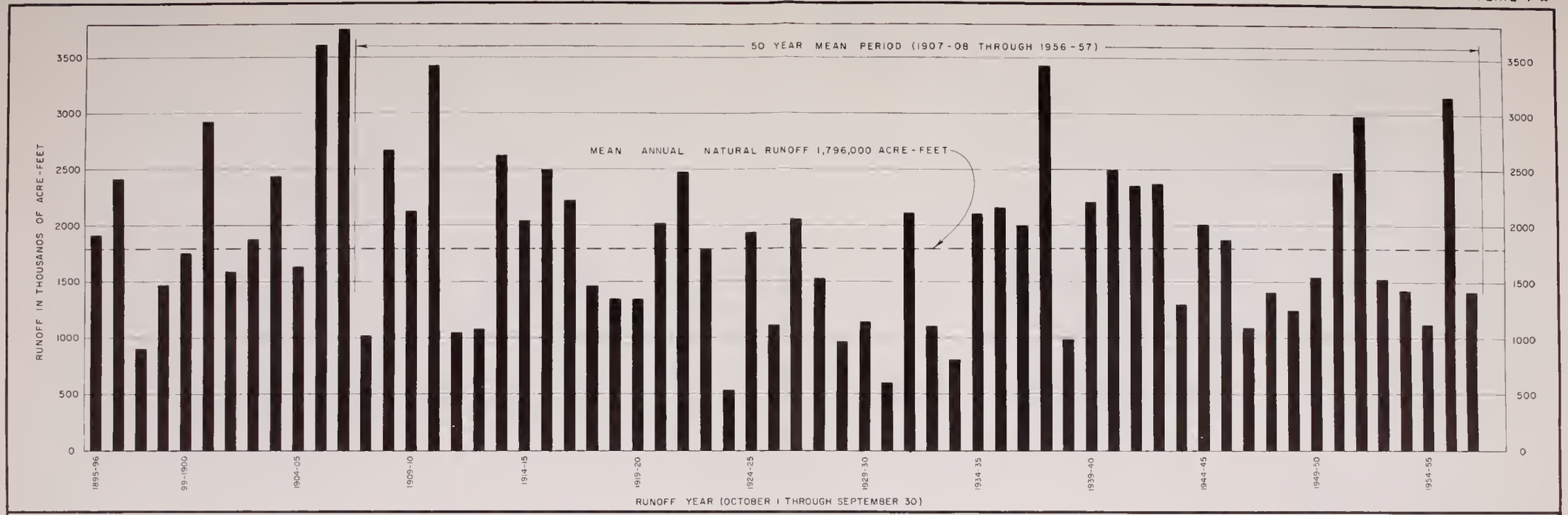
PLATE 3-B



ACCUMULATED DEPARTURE FROM MEAN ANNUAL PRECIPITATION AT HETCH HETCHY

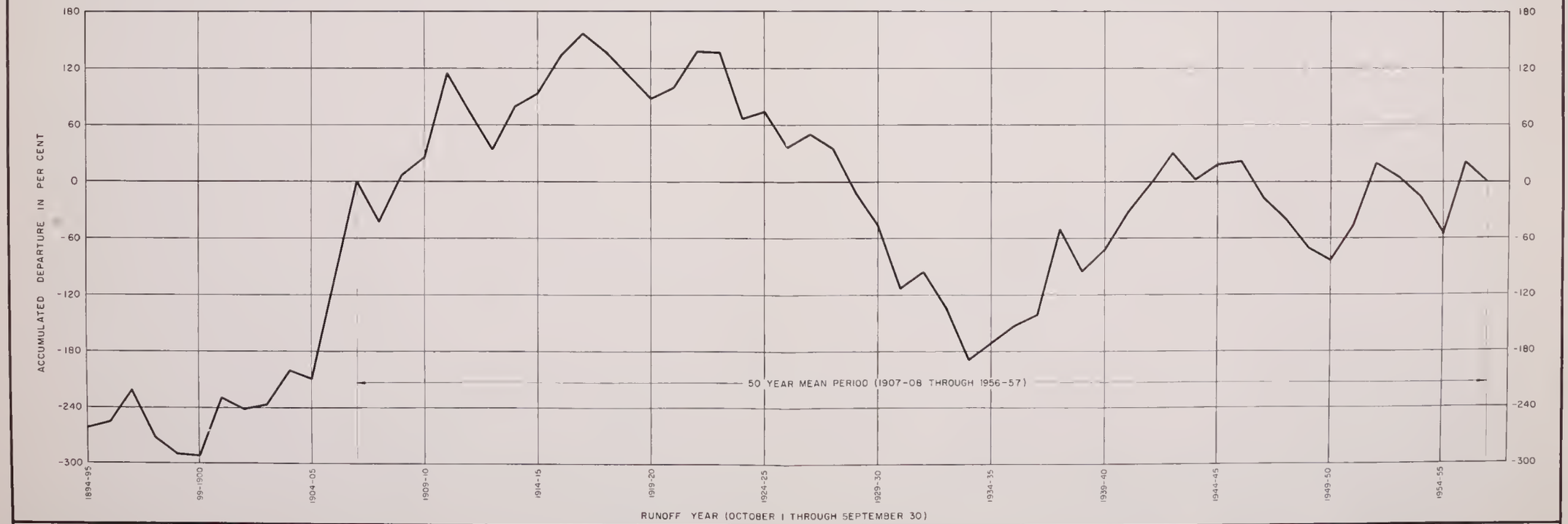
DEPARTMENT OF WATER RESOURCES 1961

PLATE 4-A



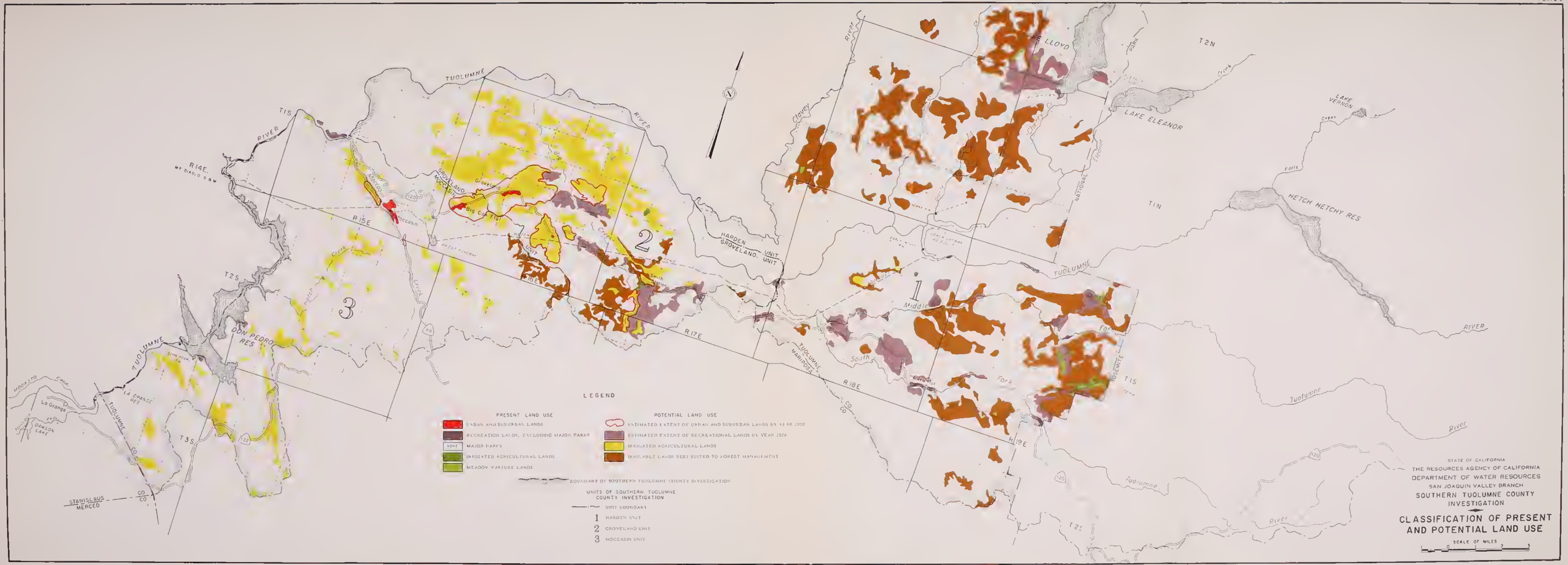
ESTIMATED ANNUAL NATURAL RUNOFF OF TUOLUMNE RIVER ABOVE LA GRANGE DAM

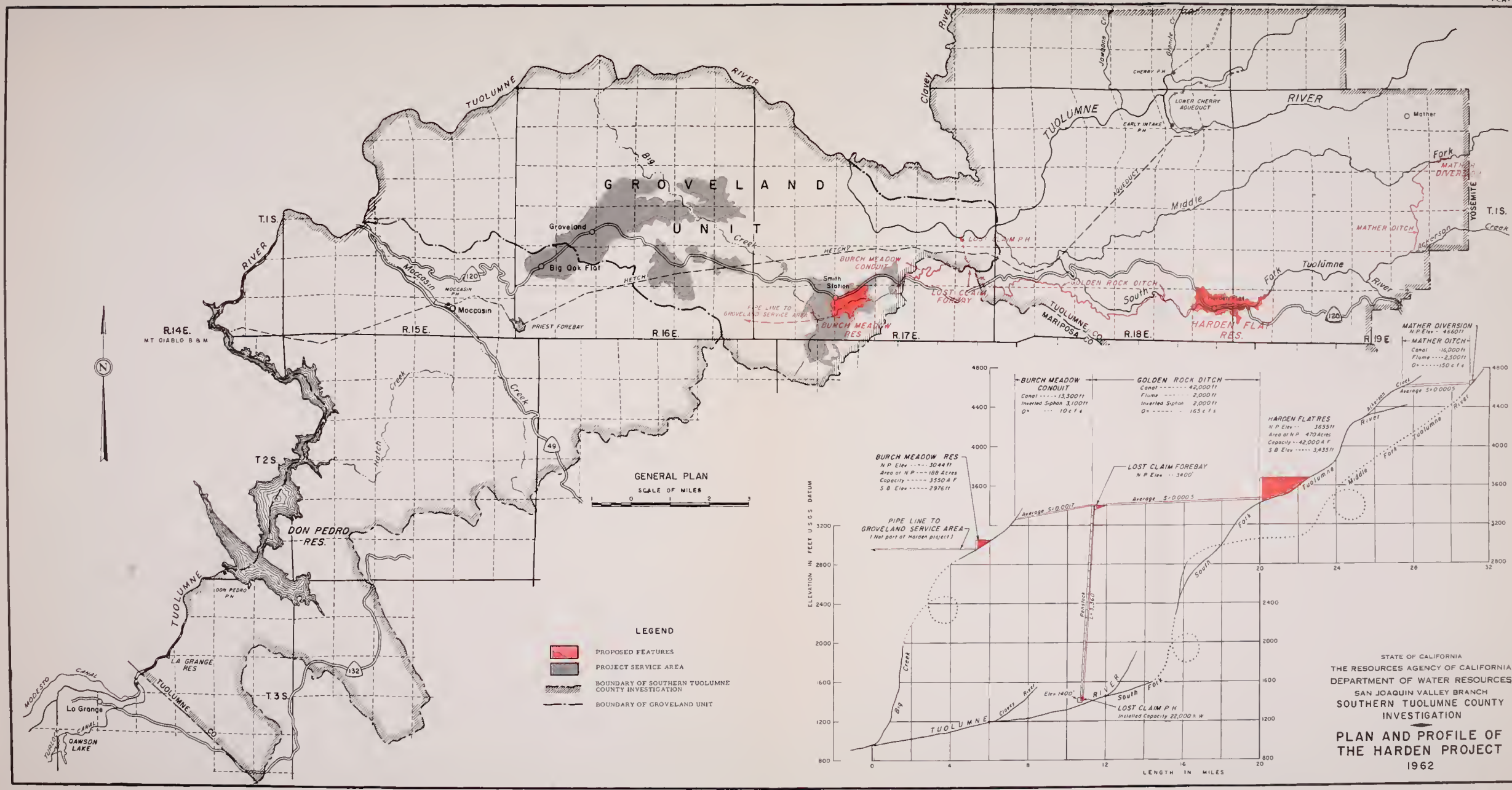
PLATE 4-B



ACCUMULATED DEPARTURE FROM MEAN ANNUAL NATURAL RUNOFF OF TUOLUMNE RIVER ABOVE LA GRANGE DAM

DEPARTMENT OF WATER RESOURCES 1961

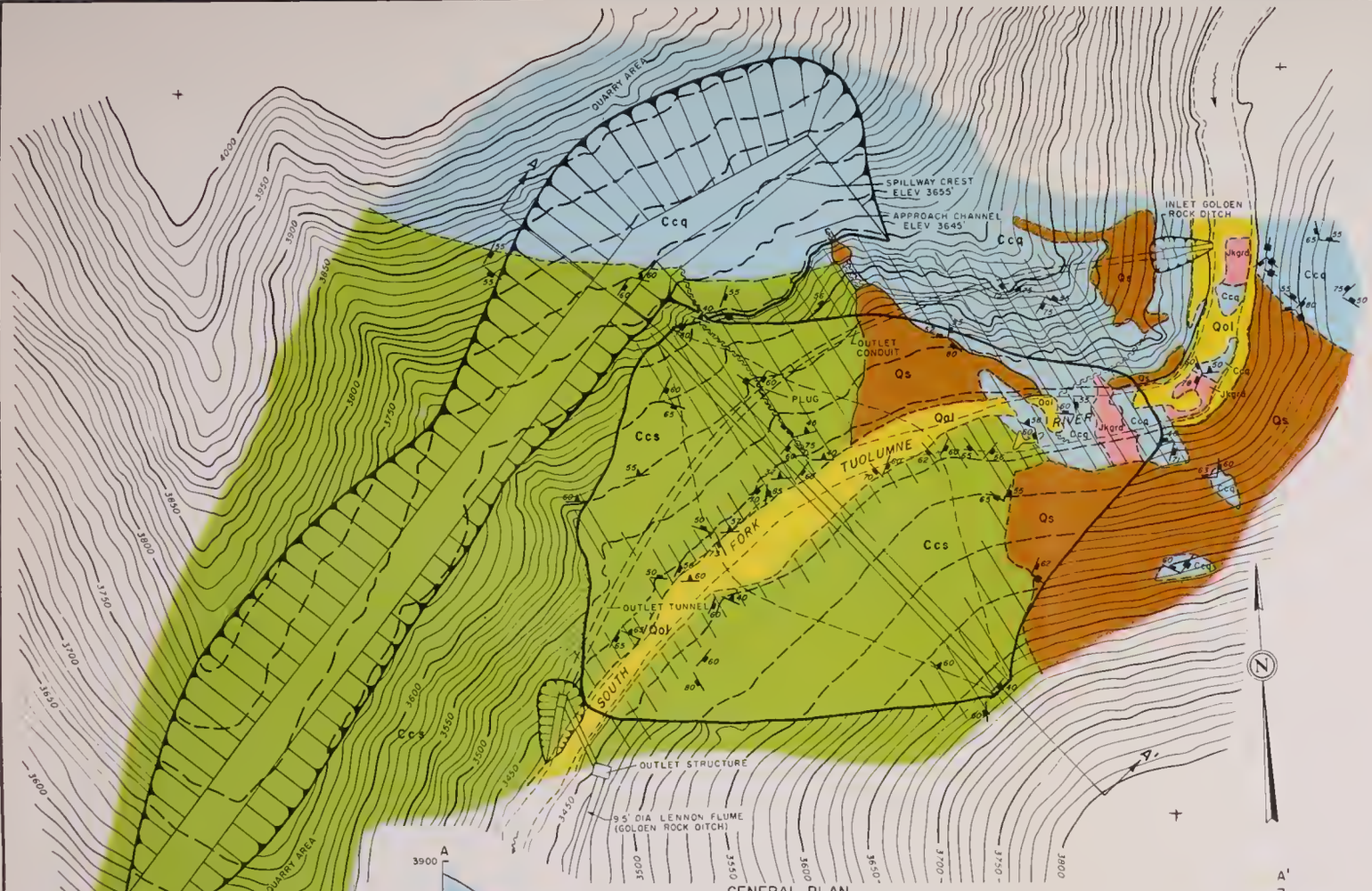

LEGEND
PRESENT LAND USE
URBAN AND SUBURBAN LANDS
RECREATION LANDS, EXCLUDING MAJOR PARKS
MAJOR PARKS
IRRIGATED AGRICULTURAL LANDS
MEADOW PASTURE LANDS
POTENTIAL LAND USE
ESTIMATED EXTENT OF URBAN AND SUBURBAN LANDS BY YEAR 2020
ESTIMATED EXTENT OF RECREATIONAL LANDS BY YEAR 2020
IRRIGATED AGRICULTURAL LANDS
IRRIGABLE LANDS BEST SUITED TO FOREST MANAGEMENT
BOUNDARY OF SOUTHERN TUOLUMNE COUNTY INVESTIGATION
UNITS OF SOUTHERN TUOLUMNE COUNTY INVESTIGATION
UNIT BOUNDARY
1 HARDEN UNIT
2 GROVELAND UNIT
3 MOCCASIN UNIT
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN VALLEY BRANCH
SOUTHERN TUOLUMNE COUNTY INVESTIGATION
CLASSIFICATION OF PRESENT AND POTENTIAL LAND USE
SCALE OF MILES
TUOLUMNE RIVER
DON PEDRO RES
LA GRANGE RES
LAKE ELEANOR
HETCH HETCHY RES
LAKE VERNON
HARDEN GROVELAND UNIT
GROVELAND
MOCCASIN
LA GRANGE
DON PEDRO
TUOLUMNE CO
STANISLAUS CO
MERCED CO
MARIPOSA CO
YOSEMITE NATIONAL PARK
T1S
T2S
T3S
T1N
T2N
R14E
R15E
R16E
R17E
R18E
R19E



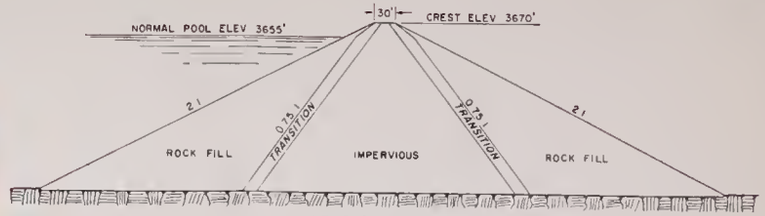
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN VALLEY BRANCH
SOUTHERN TUOLUMNE COUNTY INVESTIGATION

PLAN AND PROFILE OF THE HARDEN PROJECT

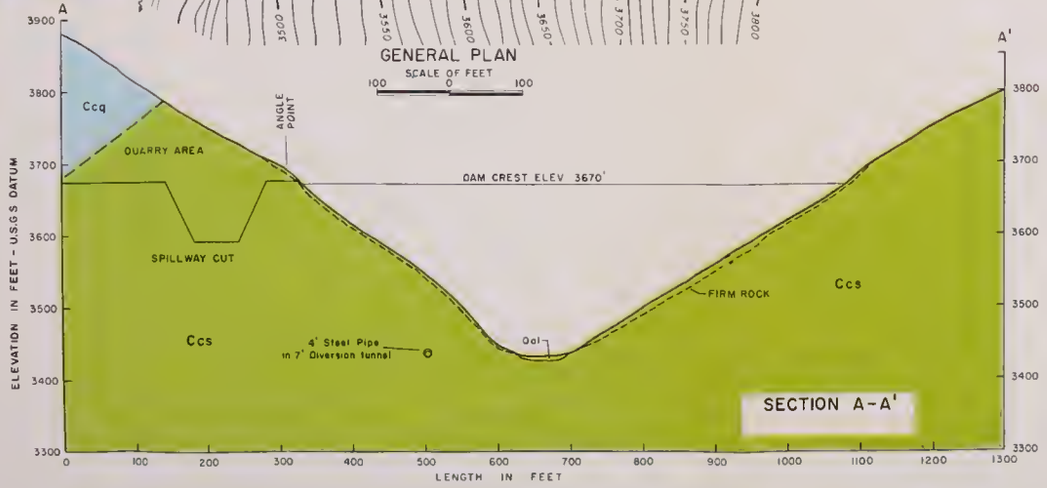
1962



GENERAL PLAN
SCALE OF FEET
100 0 100



SECTION OF DAM
SCALE OF FEET
100 0 100



LEGEND

Qal — ALLUVIUM
SAND AND GRAVEL ACCUMULATIONS, POORLY SORTED AND UNCONSOLIDATED.

Qs — TALUS AND SLOPEWASH (Undifferentiated)
TALUS - ANGULAR ROCK FRAGMENTS UP TO 6' ON AT THE BASE OF HILL SLOPES, UNSORTED, UNCONSOLIDATED, AND UNSTABLE
SLOPEWASH - ANGULAR ROCK FRAGMENTS, HUMUS AND SOIL, UNSORTED, LOOSE AND OFTEN UNSTABLE
THE TALUS AND SLOPEWASH GRADE LATERALLY INTO EACH OTHER

CALAVERAS GROUP

Ccq — QUARTZITE
HARD, WELL JOINTED, LOCALLY INTERBEDDED WITH QUARTZ MICA SCHIST. LOCALLY SHEARED AND HIGHLY CONTORTED LOCALLY COVERED BY UNMAPPED TALUS AND SLOPEWASH

Ccs — SCHIST
HARD, PROMINENTLY JOINTED. LOCALLY COVERED BY UNMAPPED TALUS AND SLOPEWASH

GRANITIC ROCKS

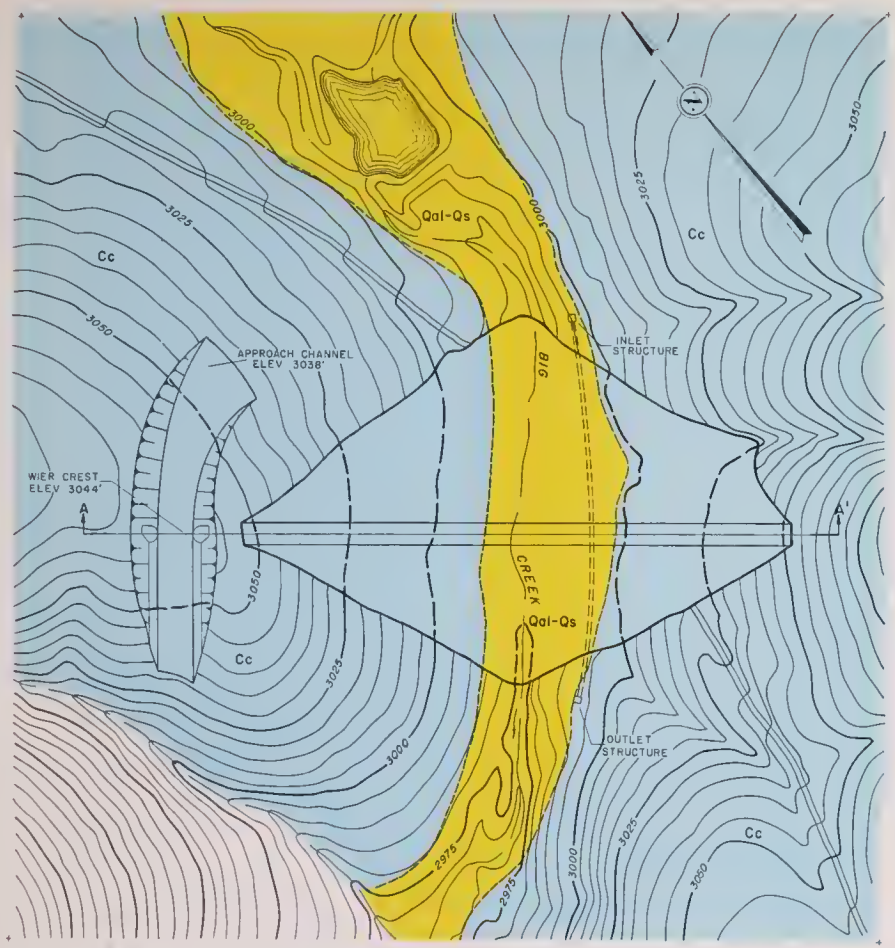
Jkgrd — MEDIUM-GRAINED GRANITE TO GRANODIORITE, HARD, VARIABLY JOINTED

SYMBOLS

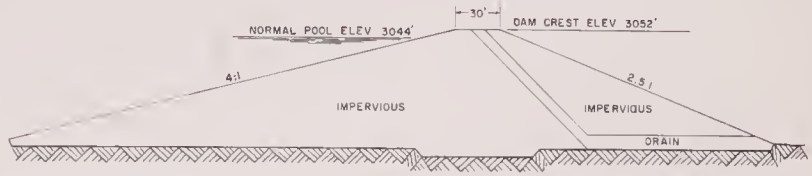
GEOLOGIC CONTACT (approximate)
JOINT, VERTICAL
JOINT, DIPPING
60
FOLIATION, DIPPING
60
SHEAR
AREAS OF NUMEROUS ROCK OUTCROPS OR THIN SOIL DEVELOPMENT

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN VALLEY BRANCH
SOUTHERN TUOLUMNE COUNTY INVESTIGATION

HARDEN FLAT DAM ON SOUTH FORK TUOLUMNE RIVER
1962



GENERAL PLAN
SCALE OF FEET
100 0 100



SECTION OF DAM
SCALE OF FEET
50 0 50

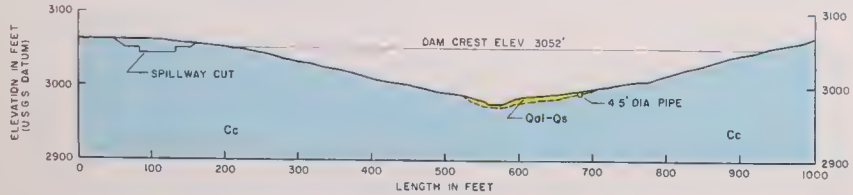
LEGEND

Qal-Qs — ALLUVIUM-COLLUVIUM (UNDIFFERENTIATED)
GRAVEL, SAND AND FINES DEPOSITED BY WATER AND GRAVITY, POORLY SORTED TO UNSORTED, LOOSE, UNCONSOLIDATED, UNITS GRADE INTO EACH OTHER VERTICALLY AND HORIZONTALLY, OFTEN INDISTINGUISHABLE

Cc — CALAVERAS GROUP
SCHIST, HORNFELS, QUARTZITE AND ASSOCIATED METAMORPHIC ROCKS, BEDDED, UNIT GENERALLY IS DEEPLY WEATHERED NEAR THE GROUND SURFACE

SYMBOLS

GEOLOGIC CONTACT

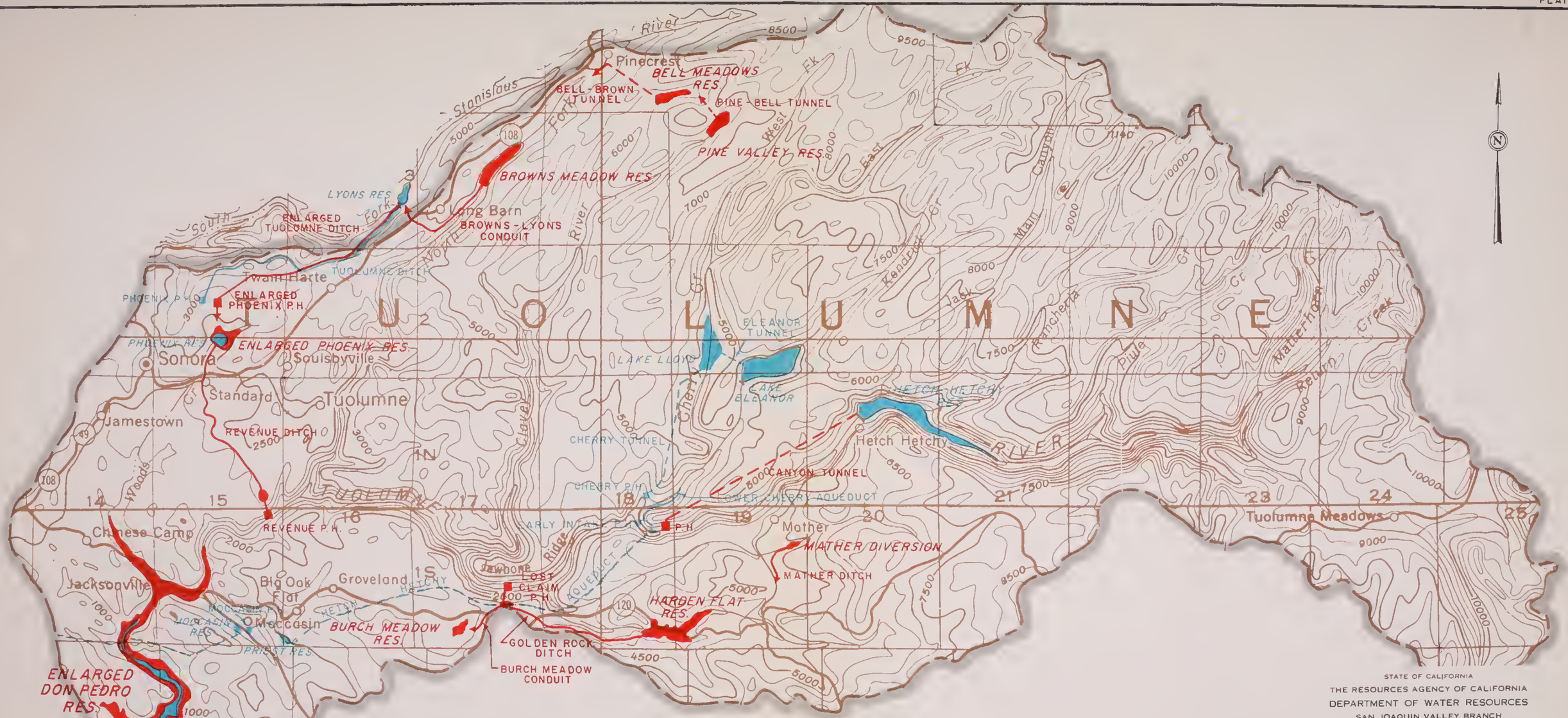


SECTION A-A'

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN VALLEY BRANCH
SOUTHERN TUOLUMNE COUNTY INVESTIGATION

BURCH MEADOW DAM ON BIG CREEK

1962



LEGEND

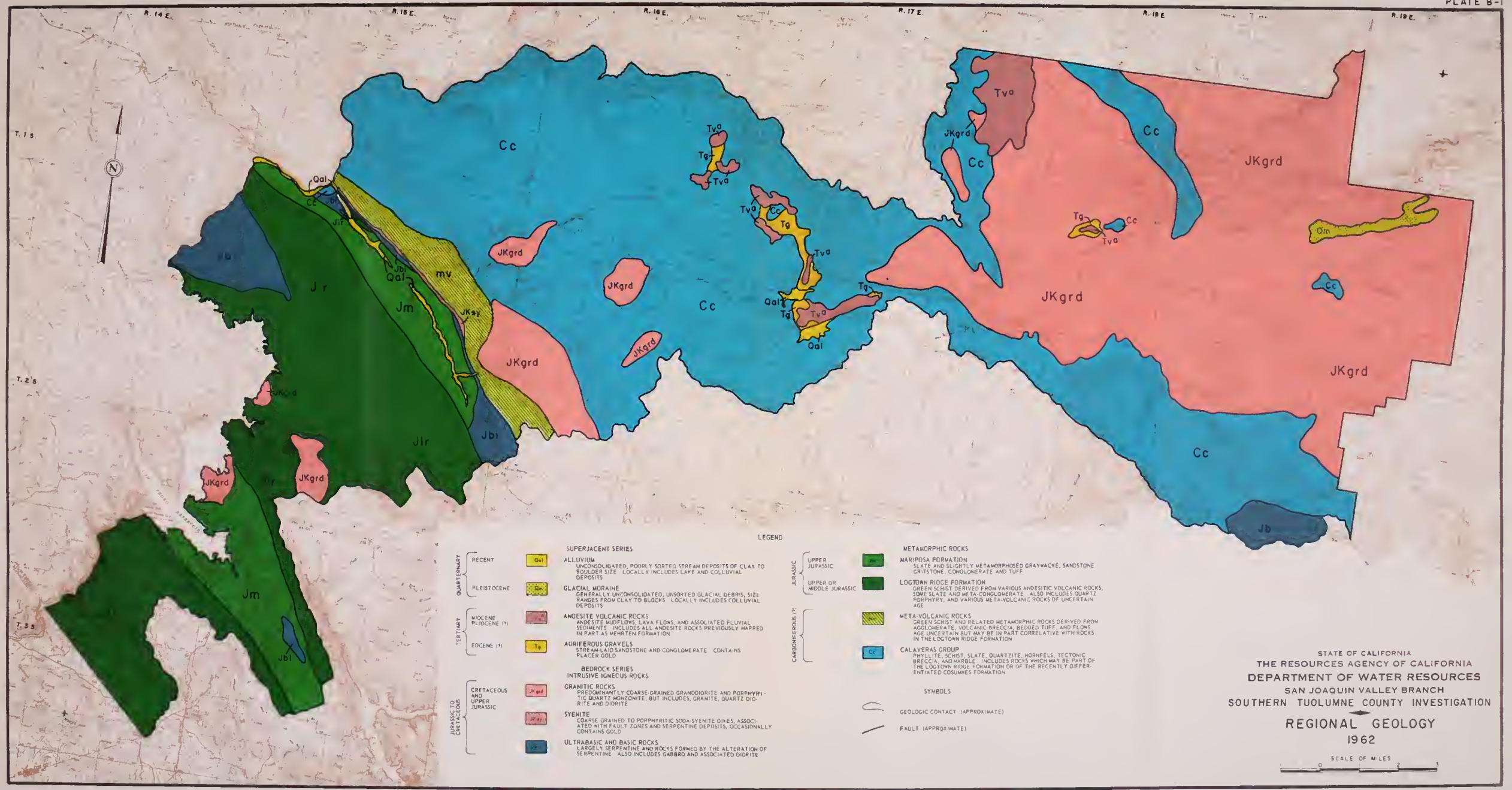
- POSSIBLE FEATURE
- EXISTING FEATURE
- BOUNDARY OF TUOLUMNE RIVER BASIN

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN VALLEY BRANCH
SOUTHERN TUOLUMNE COUNTY INVESTIGATION

POSSIBLE FEATURES OF BASIN PLANS FOR WATER DEVELOPMENT IN THE TUOLUMNE RIVER BASIN

1962

SCALE OF MILES
0 6 12



STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN VALLEY BRANCH
SOUTHERN TUOLUMNE COUNTY INVESTIGATION

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